Appendix A1. Delta Monthly Water Budgets for Operations Modeling of the Delta Wetlands Project

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SUMMARY

This appendix describes the two monthly Delta water budgets required for modeling Delta Wetlands (DW) project operations using the Delta Standards and Operations Simulation (DeltaSOS) model, which was developed by Jones & Stokes Associates (JSA) to represent possible DW operations under various scenarios for Delta conditions and standards. The Delta boundary water budget for DeltaSOS simulations represents systemwide hydrology, including operations of upstream reservoirs, inflows to the Delta, Delta channel depletions, Delta exports, and Delta outflow. The DW island water budget represents water use on the DW project islands and includes rainfall, consumptive use, and channel depletion.

The boundary water budget is based on results from DWRSIM, the Delta operations model used by California Department of Water Resources (DWR). The DeltaSOS water budget terms are based on DWRSIM simulations that assumed compliance with the objectives specified in the 1995 Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (1995 WQCP) and land use demands projected to exist in 1995. DWRSIM was used by California State Water Resources Control Board (SWRCB) to evaluate the 1995 WQCP objectives and is the most commonly used model to evaluate California water management alternatives.

The reliability of the DWRSIM simulations was confirmed by comparison of DWRSIM input assumptions and output with historical streamflow and reservoir storage measurements and unimpaired streamflow estimates. The general agreement between these historical and simulated values supports the adequacy of the DWRSIM simulations that were used to describe the Delta boundary water budget; the simulations therefore provide a reasonable basis for evaluating DW project operations and potential environmental impacts under a variety of operating criteria, existing Delta standards, and hydrologic conditions using DeltaSOS.

The DW island water budget is based on the general water budget estimated for the portion of the Delta islands constituting irrigated Delta lowlands. The average monthly values for DW island water budget terms are based on DeltaDWQ model results for water years 1967-1991 (as presented in Appendix C4, "DeltaDWQ: Delta Drainage Water Quality Model"). Some of the basic data needed to estimate the DW island water budget terms are measurable (presented in this appendix); other values must be estimated indirectly. The estimated water budget for the DW project islands is adequate for DeltaSOS modeling of DW project impacts.

The DeltaSOS model uses the calculated change in the DW island water budget between intensified agricultural use and DW project operations to adjust the channel depletion values from DWRSIM. DeltaSOS is then used to simulate monthly DW project operations, as controlled by the DWRSIM initial Delta boundary water budget, appropriate Delta objectives and requirements, and selected DW operating criteria.

INTRODUCTION

Purpose of This Appendix

The purpose of this appendix is to describe the monthly Delta water budgets used as input to the Delta-SOS model. DeltaSOS simulations were used to assess potential impacts of each of the DW project alternatives on water supply, Delta channel hydrodynamics, water quality, and fisheries (see Chapters 3A, 3B, 3C, and 3F, respectively).

Two monthly Delta water budgets are needed to evaluate likely effects of DW project operations. One consists of Delta boundary (systemwide) estimates of Delta inflows, exports, and outflow; the boundary water budget is based on results from DWR's Delta operations model, DWRSIM. The other water budget represents water use estimated for operations on the DW project islands and consists of estimates for rainfall, evaporation or crop evapotranspiration (ET), soil moisture, seepage, applied irrigation and salt leaching water, and drainage water. Both the Delta boundary and DW island monthly water budgets are described in this appendix, and their reliability for use in the DeltaSOS model are confirmed.

Reliability of Operations Modeling of the DW Project

The DeltaSOS model was developed by JSA to represent possible DW operations in the context of various scenarios for Delta conditions and standards. DeltaSOS operations modeling of the DW project uses results of DWRSIM study "1995-C6B-SWRCB-409", performed in January 1995 by DWR to evaluate proposed 1995 WQCP objectives. These simulations assume current Delta facilities and operational constraints and the 1995 level of development, in addition to 1995 WQCP objectives. These DWRSIM results were used as the initial Delta water budget for DeltaSOS simulations of channel flows, outflow, exports, and DW operations under a wide variety of hydrologic conditions for each of the DW project alternatives, based on the 70-year hydrologic record for water years 1922-1991. DeltaSOS is described in Appendix A2, "DeltaSOS: Delta Standards and Operations Simulation Model". Details of the application of DeltaSOS to evaluation of the DW project alternatives and DeltaSOS results are provided in Appendix A3, "DeltaSOS Simulations of the Delta Wetlands Project Alternatives".

DeltaSOS does not simulate operations of upstream Sacramento or San Joaquin River reservoirs nor the operations of south-of-Delta aqueducts or reservoirs. Direct simulation of likely effects of full integration of the proposed DW project with State Water Project (SWP) and Central Valley Project (CVP) operations is not possible with DeltaSOS.

DWRSIM results provide a simplified representation of CVP and SWP operations that were used as a basis for assessing water supply effects of the proposed DW project. "Delta Monthly Water Budget Simulated by DWRSIM", below, describes DWRSIM simulations of operations of upstream reservoirs and presents the historical operations of these reservoirs for water years 1967-1991 for confirmation of modeling results. Historical Delta inflows, exports, and outflows for water years 1967-1991 are also documented in this section. This 25-year period was selected for confirmation of DWRSIM simulations because nearly all CVP and SWP facilities were operating during these years. Demands for Delta exports increased substantially during this period to approximately 6 million acre-feet per year (MAF/yr) in 1989 and 1990. All references to hydrologic data and simulation results are based on water years (October-September).

Operations modeling for the DW project is designed to provide a measure of the relative effects of various DW project alternatives under constant sets of systemwide assumptions. DeltaSOS is used to simulate Delta conditions that are consistent with assumed systemwide hydrology and export demands and that satisfy assumed objectives governing Delta conditions. Relative environmental effects can then be evaluated by comparing DeltaSOS results for operation of each DW project alternative with those for operations under the No-Project Alternative. The comparison of relative effects between the simulation cases for the DW project alternatives and the No-Project Alternative is the primary focus for impact analysis. The fact that the set of systemwide assumptions on hydrology and demands used in DWRSIM and DeltaSOS have unknown or uncertain accuracy is therefore not crucial for the purposes of comparative impact analysis between alternatives. It is important, nevertheless, to demonstrate that DWRSIM results provide a reasonable representation of conditions that can be expected in the Delta under the 1995 WQCP objectives and operating criteria for the SWP and the CVP. The impacts that are simulated and discussed in this EIR/EIS are representative of the range of effects that would be expected under actual operations of the DW project.

DeltaSOS is a tool for evaluating Delta environmental impacts on a monthly average time scale under a wide range of hydrologic conditions. The likely effects of daily Delta conditions on operations of the proposed DW project are described in Appendix A4, "Possible Effects of Daily Delta Conditions on Delta Wetlands Project Operations and Impact Assessments". Both monthly and daily simulation results will be used for establishing final project capacities or operating constraints.

DELTA MONTHLY WATER BUDGET SIMULATED BY DWRSIM

DWRSIM Model Description

DWRSIM is the DWR monthly planning model for California, which simulates potential operations of the major SWP and CVP project facilities with specified operational constraints, such as 1995 WQCP objectives and export limits (DWR 1985). The DWRSIM model was based on a general HEC-3 reservoir system analysis program but has been extensively modified to simulate many unique features of the CVP and SWP facilities and operations (DWR 1986). Several additional features have been added to properly represent the 1995 WQCP objectives. The DWRSIM model was used by SWRCB to evaluate the likely water supply effects of the WQCP compared with existing Delta operating objectives, and is one of the most widely used water resource planning models for California (SWRCB 1995).

Streams and Facilities Modeled in DWRSIM

Figure A1-1 shows the major streams and facilities that are included in the DWRSIM model. The two major streams tributary to the Delta are the Sacramento River and San Joaquin River. The DWRSIM simulates some, but not all, of the major tributary facilities. The simulation of upstream facility operations is important because some of these operations are controlled by Delta outflow requirements and export limits. The reservoir releases are also governed by flood control storage rules, instream flow requirements, power generation constraints, and upstream diversion targets. The following overview of these upstream facilities included in DWRSIM will help the reader understand and evaluate the DWRSIM-simulated Delta boundary water budget.

Because the major upstream SWP storage facility is Oroville Reservoir, located on the Feather River, the Feather River is simulated in DWRSIM. Oroville Reservoir, with a capacity of about 3.5 MAF, releases water for Feather River diversions, Delta outflow requirements, and Delta exports into the California Aqueduct. Thermalito Forebay and Afterbay act as regulating reservoirs for peaking power releases from Oroville Reservoir. Oroville-Thermalito can be operated as a pumped-back facility for peaking power generation.

The Yuba River, a major tributary of the Feather River, is not modeled by DWRSIM because operations of the major storage reservoir, New Bullards Bar, are controlled by Yuba County Water Agency. The monthly operations of several local water resource facilities, such as New Bullards Bar, are assumed to remain unchanged by potential SWP operations, and are specified as fixed time-series inputs to DWRSIM.

The Trinity River is included in DWRSIM because major CVP facilities have been constructed on the Trinity River to store water and divert it to the Sacramento River. Clair Engle Reservoir has a capacity of about 2.5 MAF. Lewiston Reservoir acts as a regulating reservoir for peaking power releases from Clair Engle Reservoir and as the diversion intake for the Judge Francis Carr tunnel and power plant, which releases into Whiskeytown Reservoir. Whiskeytown Reservoir, with a capacity of about 225 thousand acre-feet (TAF) on Clear Creek, provides seasonal storage and diversions to the Spring Creek power plant, which releases into Keswick Reservoir on the Sacramento River.

Shasta Reservoir, with a capacity of about 4.5 MAF, is the largest CVP storage facility and releases water for Sacramento Valley diversions, Delta outflow requirements, and Delta exports into the Delta-Mendota Canal (DMC). Keswick Reservoir acts as a regulating reservoir for Shasta Reservoir and Spring Creek peaking hydropower releases. Major diversions from the Sacramento River are simulated at the Red Bluff Diversion Dam for the CVP Corning and Tehema-Colusa Canals. Several major diversions on the Sacramento River that are not associated with CVP or SWP "contractors", such as the Glenn-Colusa Irrigation District, are simulated in DWRSIM with relatively fixed monthly diversion targets.

Folsom Reservoir, with a storage capacity of about 1 MAF, is another important CVP storage facility, located on the American River. Lake Natoma acts as a regulating reservoir for peaking power releases from Folsom Reservoir. Downstream releases supply local diversions, instream flows, Delta outflow requirements, and Delta exports into the DMC.

All the remaining tributary streams, including the entire San Joaquin River, are specified as fixed monthly time-series inputs in DWRSIM. Because of the 1995 WQCP pulse-flow requirements for the San Joaquin River and investigations of potential increased instream flows on the Stanislaus River below the CVP New Melones Reservoir (2.4-MAF capacity), DWR has developed a separate simulation model for the Stanislaus River. However, this is used to generate a monthly San Joaquin River inflow sequence for DWRSIM input. None of the San Joaquin River tributary reservoirs are simulated in DWRSIM. Westside streams, such as Stony, Cache, and Putah Creeks, are simulated in DWRSIM; monthly estimates of flows from these streams are included as local inflow inputs.

San Luis Reservoir, located south of the Delta adjacent to the California Aqueduct and the DMC is a joint CVP and SWP storage facility with a capacity of about 2 MAF. It is operated to store Delta exports for later release during the irrigation season. It is an important feature of the SWP and CVP projects because it allows Delta exports to be pumped during periods of high Delta inflows prior to the peak seasonal demands for irrigation water.

The DWRSIM model also includes the pumping, diversion, and storage facilities along the California Aqueduct. While the total demands for Delta exports are important, simulations of these individual south-of-Delta facilities are not necessary for purposes of Delta simulations and evaluations of likely DW operations.

The next section describes the hydrologic inputs used in DWRSIM and compares simulated upstream reservoir operations with historical reservoir operations for the period of water years 1967-1991, when most SWP and CVP facilities were constructed and operating.

Overview of DWRSIM Modeling Assumptions

DWRSIM operations modeling requires input assumptions about monthly inflows, monthly channel depletions, and demands for diversions for the combined SWP and CVP systems and other nonproject demands. Assumptions about inflows can be confirmed with estimates of unimpaired flow in each of the major rivers. Depletions and diversions are generally not measured, however, so these assumptions can only be indirectly confirmed by comparing the results from DWRSIM simulations with measured downstream flows. The following sections describe the DWRSIM hydrologic inputs and describe Delta inflows, outflows, and exports simulated by this DWRSIM study. Records of historical flows and reservoir operations for 1967-1991 provide general confirmation of these DWRSIM results for the period when most SWP and CVP facilities were completed and operating.

DWRSIM inputs and simulated outputs sometimes differ from historical measurements and unimpaired flow estimates because not all historical conditions can be modeled with a single simulation that assumes a particular set of facilities and water demands.

Table A1-1 presents average values for DWRSIM inputs, DWRSIM-simulated outputs, estimates of unimpaired flows, and historical flow measurements at upstream and Delta locations. Corresponding annual values for each year of the 70-year hydrologic record are presented in Table A1-2 and in Figures A1-2 through A1-25, and are described in the following sections. These historical data demonstrate the adequacy of the DWRSIM simulations used to describe the Delta boundary water budget. The DWRSIM results therefore provide a reasonable basis for comparative evaluation of DW project operations and potential environmental impacts.

Upstream Flows and Reservoir Operations

This section presents four types of monthly data for various parameters of upstream hydrology:

- values assumed as input to DWRSIM;
- values simulated as output by DWRSIM study 1995-C6B-SWRCB-409;
- unimpaired flow values (natural flow), defined as flow measurements adjusted to compensate for measured storage changes and estimated diversion upstream of the measurement station; and
- historical measured flow values, with no compensation for upstream water development.

The DWRSIM hydrologic input data set incorporates estimates of unimpaired runoff from streams tributary to the Delta combined with estimates of upstream depletions and reservoir storage effects. Land use in the basin influences the upstream depletion estimates. The depletion estimates used to develop the DWRSIM input data were based on assumed land use patterns representing the current 1995 level of development. Total annual hydrology inputs for DWRSIM were often slightly less than or equal to unimpaired flow estimates. Unimpaired flow estimates represent the maximum possible flow at a location, and thus should be larger than both historical and simulated values, unless there are major diversions between rivers. DWRSIM input data for each major reservoir can be compared with unimpaired streamflow estimates at each reservoir location to identify the magnitude of upstream diversions and storage adjustments.

The major hydrologic inputs for DWRSIM are the reservoir inflows and local inflows from each tributary stream. Table A1-2 presents the annual upstream unimpaired flows and DWRSIM inputs for the Trinity River and Sacramento River tributaries for water years 1922-1991. The annual inflows are used to classify each water year according to various water-year-type classification schemes. Delivery deficiencies, instream flows, and Delta outflow requirements may depend on the year type. The Shasta inflow is used in several CVP water contracts. The 1995 WQCP uses a "40-30-30" weighted classification (see footnote 2 of Table 1 of the 1995 WQCP) of the Sacramento Valley Four-River Runoff Index, which is the sum of the runoff of the Sacramento River at Bend Bridge and the Feather, Yuba, and American Rivers. The water-year period runs from October to September, but the year type cannot be accurately determined until March or April, when the bulk of precipitation has been recorded as rain or snowpack measurements.

Table A1-2 indicates that there is considerable variation in Trinity River and Sacramento River runoff from one water year to the next. The DWRSIM model simulates the operation of the CVP and SWP reservoir system and Delta exports for the historical sequence of inflows, as though they were to be repeated in the future with current reservoirs, diversion demands, specified instream flow requirements and Delta objectives. The DeltaSOS model is used to simulate potential operation of the DW project within the historical hydrologic variability and likely future operations of the SWP and CVP facilities.

Figure A1-2 shows annual values for DWRSIM model inputs for Clair Engle Reservoir inflows on the Trinity River for water years 1922-1991. Unimpaired flow estimates for the Trinity River at Lewiston are shown for comparison. The overall average for the DWRSIM Trinity River inflows for 1922-1991 is 1,218 thousand acre-feet per year (TAF/yr), which is very close to the estimate of unimpaired average annual flow at Lewiston of 1,245 TAF/yr. Annual inflow estimates for Clair Engle Reservoir ranged from 227 TAF/yr in 1977 to 2,887 TAF/yr in 1983.

Figure A1-3 shows annual values for DWRSIM inputs and unimpaired flow estimates for Trinity River flows below Clair Engle Reservoir for 1922-1991. Trinity River minimum flows of 340 TAF/yr are currently required downstream of Clair Engle Reservoir (under evaluation by U.S. Fish and Wildlife Service). Most of the remaining inflow is diverted to the Sacramento River by CVP facilities, although flows have spilled to the Trinity River in some wet years. The 1922-1991 average simulated Trinity River flow was 369 TAF.

The CVP Trinity River diversions directly affect Sacramento River flows and Delta inflows. The simulated average annual diversion for 1922-1991 is 882 TAF/yr, and Trinity River diversions averaged 1,027 TAF/yr for historical values and 1,024 TAF/yr for DWRSIM results for 1967-1991 (Table A1-1). Figure A1-4 shows the historical and simulated values for monthly Trinity River diversions via the J. F. Carr Tunnel to Whiskeytown Reservoir for 1967-1991. The 1967-1991 monthly DWRSIM results generally follow the seasonal pattern of the historical diversions. Historical monthly average diversions ranged from no diversions in winter of some years to about 3,500 cubic feet per second (cfs) in fall 1969. Monthly simulations by DWRSIM never exceed 3,300 cfs nor fall below 250 cfs.

Simulated values for most years generally follow historical records for end-of-month Clair Engle Reservoir storage for 1967-1991 (Figure A1-5). Simulated values differ from historical records during dry years, when reservoir operations are most sensitive to the simulated operations criteria. Typically, Clair Engle Reservoir is operated with a maximum storage of 2,500 TAF and an annual drawdown of approximately 750 TAF. Minimum carryover storage in 1967-1991 was 250 TAF at the end of water year 1977. During periods of drought, annual drawdown increased to approximately 1,000 TAF. Differences between simulated and historical Trinity River diversions correspond with differences in simulated and historical Clair Engle Reservoir storage patterns.

The historical and simulated reservoir operations can be summarized with the September end-of-month carryover storage for each water year. Table A1-3 gives the historical and simulated carryover storage for Clair Engle Reservoir and the other major reservoirs simulated by DWRSIM. The simulated carryover storage would be expected to be most similar to the historical values during the 1967-1991 period, when most CVP and SWP facilities were constructed and operating. However, many of the simulated flood control requirements, instream flow requirements, and Delta WQCP objectives for outflow or export are different from the historical conditions and constraints.

Figure A1-6 compares DWRSIM inputs and unimpaired flow estimates for annual inflows to Shasta Reservoir for 1922-1991. The 1922-1991 average annual model input for Shasta Reservoir inflow was 5,555 TAF/yr, and the average annual unimpaired flow estimate was 5,560 TAF/yr (Table A1-2). Estimates of annual inflow to Shasta Reservoir ranged from about 2,500 TAF/yr (1924, 1931, 1977) to more than 10,000 TAF/yr (1974, 1983). The 1967-1991 average was 5,985 TAF/yr.

Figure A1-7 shows end-of-month Shasta Reservoir storage for 1967-1991, as simulated by DWRSIM and as measured historically. Historical and simulated values generally correspond, except during the drought period of 1976-1977, when simulated storage values exceeded historical levels by approximately 1,000 TAF. Storage capacity at Shasta Reservoir is approximately 4,500 TAF, and annual drawdowns during 1967-1991 were between 1,000 TAF and 1,500 TAF. Maximum drawdown during the 1967-1991 period was about 2,000 TAF in 1981, which was classified as a dry year. During the 1976-1977 drought, Shasta Reservoir storage declined to a low of about 600 TAF. Shasta Reservoir carryover storage was about 1,500 TAF during 1987-1991 drought conditions. Simulated carryover storage remained greater than 1,000 TAF (Table A1-3).

Simulated and historical monthly flows in the Sacramento River at Bend Bridge (near Red Bluff) were similar for 1967-1991 (Figure A1-8). The average annual flows were 9,478 TAF and 9,450 TAF for the simulated and historical flows, respectively (Table A1-1). The unimpaired flow estimate at Bend Bridge for 1967-1991 (8,721 TAF) is considerably lower than the simulated and historical values because diversions from the Trinity River Basin to the Sacramento Valley are not included in the Bend Bridge unimpaired flow estimate. The average annual unimpaired flow estimate of runoff from tributary streams between Shasta Reservoir and Bend Bridge was about 2,736 TAF for the 1967-1991 period. These tributary inflows cannot be regulated by any existing reservoirs.

Monthly average flows at Bend Bridge during 1967-1991 varied from 5,000 cfs to about 75,000 cfs (Figure A1-8). Flows in the upper Sacramento River are normally highest in summer because of releases to meet irrigation demands, but during years with very high inflows to Shasta Reservoir, large flow-control releases in late winter and early spring were necessary and resulted in very high peak flows.

Figure A1-9 shows DWRSIM inputs and unimpaired flow estimates for annual Oroville Reservoir inflows for water years 1922-1991. The unimpaired inflow estimates averaged 4,306 TAF/yr; DWRSIM input values averaged 3,889 TAF/yr (Table A1-2). This difference is attributable to assumed upstream uses and diversions. DWRSIM (Table A1-2) indicates that annual inflow estimates vary from 750 TAF (1977) to more than 7,500 TAF (1938, 1974, 1982, 1983).

Figure A1-10 shows end-of-month Oroville Reservoir storage for 1967-1991 simulated by DWRSIM and measured historically. Generally, the reservoir is filled to approximately 3,500 TAF (reservoir capacity) in spring and lowered approximately 750 TAF in summer. During periods of drought, drawdown is greater and storage declines. The lowest carryover storage during 1967-1991 was about 900 TAF in water year 1977. Carryover storage fluctuated between about 1,000 TAF and 2,000 TAF during the 1987-1991 drought period. Simulated carryover storage was similar to historical in most years (Table A1-3).

Figure A1-11 shows the annual 1922-1991 inflow for the Yuba and Bear Rivers assumed in DWRSIM compared with the unimpaired flow estimates of the Yuba River at Smartville and the Bear River at Wheatland. The DWRSIM input for average annual Yuba River inflow was 2,899 TAF/yr, and the unimpaired flow estimate for average annual flow for the Yuba and Bear Rivers was 2,573 TAF/yr for 1922-1991 (Table A1-2). DWRSIM inflows are higher than unimpaired flow estimates because of local gains along the Yuba and Bear Rivers (below Smartville and Wheatland) during wet periods.

Figure A1-12 compares DWRSIM inputs and unimpaired flow estimates for annual Folsom Reservoir inflows for water years 1922-1991. The unimpaired flow estimates average 2,586 TAF/yr, and annual DWRSIM inputs average 2,700 TAF/yr (Table A1-1). The higher value for DWRSIM American River inflows can be generally attributed to power-generating diversions from other basins. Upstream storage differences may produce differences between model inputs and unimpaired flow estimates. DWRSIM-estimated Folsom Reservoir annual inflows varied from about 450 TAF (1977) to 6,500 TAF (1983) (Table A1-2).

Figure A1-13 shows the simulated and historical end-of-month Folsom Reservoir storage for 1967-1991. Flood control operations require that Folsom Reservoir storage is less than 600 TAF in winter. Folsom Reservoir is generally filled to 975 TAF (reservoir capacity) during spring, then lowered to the flood control storage of about 600 TAF in fall. The lowest historical carryover storage during the 1967-1991 period was 150 TAF in 1977, and carryover storage was less than 200 TAF in 1988 and 1990. Simulated carryover storage remained above 100 TAF, except in 1977 (Table A1-3).

Figure A1-14 compares the monthly simulated and historical American River flows at Fair Oaks for 1967-1991. Flows are a function of upstream reservoir operations, local diversions, and minimum required American River flows. American River monthly average flows for 1967-1991 ranged from about 500 cfs in water year 1977 to 32,000 cfs in water year 1986.

Delta Inflows

The combination of these simulated upstream reservoir operations and local inflows, minus the simulated diversions along these upstream tributaries, produce the simulated Delta inflows. Table A1-4 shows the annual historical and DWRSIM-simulated Delta inflows for water years 1922-1991. Some Sacramento River inflow is diverted into the Yolo Bypass during high-flow periods. Eastside streams include the Cosumnes, Mokelumne, and Calaveras Rivers. The San Joaquin River inflow at Vernalis includes contributions from the Stanislaus, Tuolumne, and Merced Rivers. Local runoff from rainfall events in the Delta can provide substantial inflow in some years.

Figure A1-15 shows the historical and DWRSIM-simulated annual Sacramento River and Yolo Bypass inflows to the Delta for 1922-1991. Effects of local inflows, Sacramento Valley irrigation diversions, and other consumptive uses are aggregated in these combined Sacramento and Yolo Bypass inflows. Historical flow records for Freeport commenced in 1949; data prior to 1949 are from DWR's DAYFLOW estimates (1930-1948) combined with estimates based on DWR's unimpaired monthly flow estimates (1922-1929). DAYFLOW is a database of measured daily Delta inflows and exports, and estimated outflows and consumptive use values. The average annual historical Sacramento River and Yolo Bypass flows for 1967-1991 were 17,280 TAF/yr and 3,218 TAF/yr, respectively, and the DWRSIM-simulated average inflows for 1967-1991 were 17,454 TAF/yr and 2,899 TAF/yr, respectively (Table A1-4). The year-to-year variations in historical measurements and DWRSIM simulations generally correspond well.

Figure A1-16 shows the monthly historical and DWRSIM-simulated Sacramento River and Yolo Bypass flows for 1967-1991. The historical Sacramento River flow is limited to about 80,000 cfs (channel capacity), with excess flow diverted into the Yolo Bypass. Monthly average flows of the Yolo Bypass and the Sacramento River combined during 1967-1991 have varied from about 10,000 cfs to approximately 210,000 cfs. Differences between historical and simulated monthly flows can be attributed to changes in upstream reservoir operations and upstream diversions that are reflected in the historical record but not in the simulations.

Both the San Joaquin River and eastside streams are fixed inputs for DWRSIM simulations. Figure A1-17 shows the annual DWRSIM inputs with unimpaired flow estimates and historical measurements of flows in the San Joaquin River at Vernalis for 1922-1991. Annual DWRSIM inputs for San Joaquin River flows ranged from about 950 TAF (1990) to 15,726 TAF (1983) and averaged 2,401 TAF (Table A1-4). Assumed input flows are substantially lower than estimated annual average unimpaired flows because of upstream storage and irrigation diversions assumed in the simulations (Table A1-3).

Figure A1-18 shows the DWRSIM inputs and historical measurements for monthly San Joaquin River flows for 1967-1991. Historical monthly flows range from almost no flow to peaks of greater than 40,000 cfs. DWRSIM input flows are similar to historical values during this period because most of the water facilities assumed in DWRSIM modeling were operating. The annual average historical Vernalis flow for 1967-1991 was 3,521 TAF; simulated inputs averaged 3,077 TAF (Table A1-4).

Figure A1-19 compares DWRSIM inputs, historical measurements, and unimpaired flow estimates for annual flows for eastside streams for 1922-1991. The average annual DWRSIM input for eastside stream inflow was 835 TAF/yr, and the annual average unimpaired inflow was 1,065 TAF/yr for 1922-1991 (Table A1-1).

Figure A1-20 shows the mean monthly DWRSIM inputs and DAYFLOW historical estimates for eastside stream inflows to the Delta for 1967-1991. The historical monthly eastside streamflows range from almost no flow to about 20,000 cfs. Average annual historical eastside stream inflow to the Delta during 1967-1991 was

1,163 TAF, the unimpaired flow estimate was 1,157 TAF, and the average annual DWRSIM input was 1,088 TAF (Table A1-4).

The final DWRSIM input for inflow to the Delta is local Delta runoff, estimated from Delta precipitation records and assuming complete runoff. An estimate of Delta net channel depletion is also used in DWRSIM and is calculated by subtraction of local Delta runoff estimates from Delta evapotranspiration (ET) estimates. Figure A1-21 shows the mean monthly net Delta channel depletion input to DWRSIM compared with mean monthly DAYFLOW estimates of historical Delta precipitation, ET (consumptive use), and Delta net channel depletion for 1967-1991. The monthly DAYFLOW and DWRSIM estimates of net channel depletion are similar. DWRSIM mean monthly estimated net channel depletion ranged from -8,000 cfs in water year 1986 (net runoff) to 4,500 cfs during summer (July) of each year. Average annual DWRSIM and DAYFLOW estimates of net channel depletions were 842 TAF/yr and 739 TAF/yr, respectively, for 1967-1991 (Table A1-1).

Delta Exports and Outflow

Table A1-5 gives the annual average historical and simulated Delta exports and outflow for water years 1922-1991.

DWRSIM simulates Delta exports and Delta outflow after determining the amount of Delta inflows required for Delta channel depletion. Delta export pumping occurs in four locations: CVP pumping at Tracy, SWP pumping at Banks, Contra Costa Water District (CCWD) diversions at Rock Slough, and North Bay Aqueduct pumping at Barker Slough.

DWRSIM simulates Delta exports to meet downstream monthly demands and to fill San Luis Reservoir for meeting seasonal demands, subject to 1995 WQCP Delta objectives for outflow and pumping limits. The magnitude of downstream demands is a major input assumption of DWRSIM that governs the amount of simulated Delta exports.

DWRSIM was modified for the 1995 WQCP simulations to use a variable SWP demand that depends on Kern River flow and Los Angeles rainfall (SWRCB 1995). The Metropolitan Water District of Southern California (MWD) demand varies from a maximum of 1,450 TAF in dry years to a minimum of 800 TAF in wet years. The SWP agricultural demand varies from a maximum of 1,220 TAF in dry years to a minimum of 915 TAF in wet years. The CVP Delta demands were specified as a constant 1995 level of export demand of 3,295 TAF. The CCWD demand was specified as 145 TAF/yr. However, because of incorporation into DWRSIM of limitations associated with the Coordinated Operation Agreement (COA) and WQCP Delta objectives, the DWRSIM-simulated CVP Delta exports for 1922-1991 averaged only 2,758 TAF/yr. The variable SWP demands resulted in an average simulated SWP Delta export of 2,955 TAF/yr. The simulated average annual total Delta export was 5,712 TAF/yr.

Figure A1-22 shows annual Delta CVP and SWP exports and CCWD diversions for 1922-1991 as simulated by DWRSIM and from DAYFLOW historical estimates. Historical annual exports increased to approximately 6,000 TAF during the late 1980s. DWRSIM-simulated demands totaled about 6,000 TAF throughout the simulated period, and were divided almost equally between CVP and SWP exports. CCWD diversions were fixed in DWRSIM simulations, with an average annual export value of about 146 TAF/yr.

Figure A1-23 shows mean monthly Delta exports for 1967-1991 as simulated by DWRSIM and from DAYFLOW historical measurements. Historical exports increased steadily throughout the 1967-1991 period. Simulated exports are thus much higher than historical exports in the earlier parts of the 1967-1991 period because DWRSIM-simulated exports are based on currently operating facilities and demands with 1995 WQCP Delta objectives.

Figure A1-24 shows DWRSIM-simulated and DAYFLOW estimated annual Delta outflows for 1922-1991. Simulated values are lower than estimated historical outflows in the earlier years but match better in recent years because DWRSIM simulations assume 1995 level of facilities, land use, and export demands, which approximate operations in recent years. DAYFLOW estimated Delta outflow averaged 20,368 TAF/yr for 1967-1991, and DWRSIM-simulated Delta outflow averaged 17,993 TAF/yr (Table A1-5).

Figure A1-25 shows mean monthly Delta outflow for 1967-1991, as simulated by DWRSIM and from DAYFLOW historical estimates. Differences between the simulated and historical values can be attributed to differences between simulated and historical Delta inflows, exports, or required Delta outflow standards. Historical mean monthly Delta outflows have ranged from less than 5,000 cfs to more than 250,000 cfs (water year 1983).

This section has described the DWRSIM inputs and simulated results for Delta inflows, which are based on the specified reservoir operations, instream flows, and the 1995 WQCP objectives. The comparisons with historical data for the 1967-1991 period, when most CVP and SWP facilities were constructed and operating, provides evidence that the basic DWRSIM simulations of the upstream CVP and SWP reservoirs and Delta operations are reliable. Because the impact assessments for DW operations will use incremental analysis between simulated conditions for the No-Project Alternative and each alternative, the absolute accuracy of the DWRSIM results is not crucial to the outcome of the DW impact assessments for water supply, hydrodynamics, water quality, and fisheries.

DELTA ISLAND WATER BUDGET

DW project operations would change the Delta water budget by converting No-Project Alternative intensive agricultural land use to a combination of water storage and wetland habitat management. The changes in the water budget for the DW project islands are used to modify the Delta channel depletion values from DWRSIM. The modified values are then used in DeltaSOS simulations of monthly DW project operations, as controlled by the DWRSIM initial water budget and appropriate Delta standards and selected DW operating criteria.

The Delta is traditionally divided into uplands and lowlands, based on elevation (DWR 1993). The agricultural water budget for the Delta lowlands (where the DW project islands are located) is compared with the assumed water budget for the DW project islands in this section.

Delta Agricultural Water Budget Terms

Table A1-6 gives estimated Delta areas for each major land use category. Delta uplands and lowlands include areas of open water and riparian, urban, irrigated, and natural-idle land. The natural-idle portion of the Delta is assumed not to contribute to the Delta agricultural water budget because rainfall is assumed to be retained until ET depletes the available moisture for the year.

Table A1-6 also shows assumed land use for the proposed DW habitat islands, which will include both irrigated croplands and seasonal flooded wetlands. The DW reservoir islands will generally be used for water storage but may support shallow-water wetlands in years with no available water for diversion and storage.

Delta agricultural water budget terms include rainfall, evaporation or crop ET, soil moisture storage, seepage, applied irrigation and salt leaching water, and drainage water. Table A1-7 provides estimated monthly values (in inches of water) for each water budget term for the Delta agricultural water budget. The open water, riparian, and urban areas are separated from irrigated Delta uplands and irrigated Delta lowlands.

Contributing areas and annual water volumes (TAF/yr) are also given in Table A1-7. Monthly water values can be determined by multiplying the monthly water depth (in feet) by the acreages contributing to each term.

Basic data needed to estimate the Delta island water budget terms include monthly rainfall and monthly average ET rates (estimated from crop acreages and assumed crop ET rates). Estimates of irrigation leaching fraction (i.e., ratio of drainage to applied water), seepage rates, minimum and maximum monthly soil moisture depths, and monthly drainage depths for salt leaching are more difficult to obtain. An assumed leaching fraction of 50% is used to estimate irrigation diversions and resulting drainage flows for the Delta lowlands. Under this assumption, for each inch of crop ET, 2 inches of water would be applied as irrigation water and 1 inch would appear as drainage. These assumed Delta island water budget terms are based on DeltaDWQ model results given in Appendix C4, "DeltaDWQ: Delta Drainage Water Quality Model".

For the Delta lowlands, a constant seepage of 1 inch per month is assumed to flow directly into drainage ditches and is therefore not used to satisfy crop ET. Delta lowlands also have a significant amount of water applied for salt leaching that is drained during winter to remove accumulated salts from the soil crop root zone. Leaching water is assumed to be applied in December, January, and February (6 inches per year) to approximate salt leaching water practices on the Delta lowland islands.

For example, the estimated water budget for the irrigated portion of the Delta lowlands (Table A1-7) in October has the following monthly average terms: rainfall of 0.8 inch, 4.0 inches of soil moisture (no change from end of September soil moisture), 1.4 inches of ET, 1.0 inch of seepage, and 1.2 inches of applied water (twice the water required to supply the 0.6 inch of net ET

[1.4 ET - 0.8 rainfall], with drainage of 1.6 inches (1.0 seepage + 0.6 excess applied water). Soil moisture provides a possible storage term, but it is simulated to vary between a specified minimum and maximum value. The actual monthly water budget may be different each year because rainfall, soil moisture changes, and irrigation and seepage are estimated.

As shown in Table A1-7, Delta rainfall averages about 16 inches per year, which supplies about 121 TAF/yr in the water-riparian-urban portion of the Delta, 194 TAF/yr in the irrigated uplands area, and about 465 TAF/yr in the irrigated lowlands area of the Delta (23 TAF/yr falls on the DW project islands). The total Delta rainfall volume is therefore approximately 780 TAF/yr. In comparison, DWRSIM uses an average of 830 TAF/yr as the runoff gains to the Delta.

Table A1-7 indicates that water evaporation consumes about 291 TAF/yr from the water-riparian-urban portion of the Delta. Additionally, the assumed crop ET requires about 427 TAF/yr on the irrigated uplands and about 890 TAF/yr on the irrigated lowlands (44 TAF/yr from the DW project islands). The Delta consumptive use total is therefore approximately 1,608 TAF/yr. In comparison, DWRSIM uses an average of 1,682 TAF/yr.

Table A1-7 indicates that net channel depletion, which is the difference between consumptive use and rainfall, is about 170 TAF/yr for the water-riparian-urban portion of the Delta, about 234 TAF/yr for the irrigated uplands, and about 425 TAF/yr for the irrigated lowlands (21 TAF/yr for the DW project islands). Total Delta channel depletion, estimated from this approximate monthly water budget, is therefore approximately 830 TAF/yr, somewhat less than the average Delta channel depletion of 852 TAF/yr assumed in DWRSIM. No reliable method exists for determining actual Delta runoff from rainfall or actual consumptive use.

DW Project Island Water Budget

The DW project islands are located in the Delta lowlands, so the water budget for agricultural use of the DW islands would be the same as the assumed Delta lowland water budget. Table A1-8 shows the agricultural water budget terms for the DW project islands, which include approximately 17,000 acres of irrigated cropland under the No-Project Alternative. The irrigated portions of the DW project islands represent about 5% of the irrigated Delta lowlands, so the water volume terms are expected to be about 5% of the Delta lowland water volume terms.

Table A1-8 indicates that rainfall on the irrigated portion of the DW islands would average about 23 TAF/yr. Crop ET under the No-Project Alternative would consume about 44 TAF/yr, so channel depletion for the DW islands would average 21 TAF/yr. Table A1-8 indicates that seepage onto the DW islands would amount to approximately 17 TAF/yr, applied salt leaching water would average about 9 TAF/yr, and applied irrigation water would amount to about 51 TAF/yr. The resulting drainage from the seepage, applied salt leaching water, and excess irrigation water (50% leaching fraction) would total about 56 TAF/yr.

The best available data for confirming the agricultural drainage estimates for the DW project islands are drainage pump power records. Electricity usage is converted to flow volumes using pump efficiency test results obtained from Pacific Gas and Electric Company (PG&E), expressed as acre-feet per kilowatt-hour (af/kWh). DW obtained monthly PG&E power consumption records and estimated pumping volumes for the four DW project islands for 1986-1992. Table A1-9 presents these monthly and annual pumping values for the DW project islands, in inches per month of drainage from the entire island area.

The estimated monthly drainage volumes for the DW islands were quite variable between islands as well as between months. Monthly pumping estimates have varied from less than 1 inch to more than 10 inches. Annual estimates for individual islands have varied from 11 inches to more than 75 inches. Drainage volumes have generally followed a double-peak pattern, with high pumping in winter because of excess rainfall and salt leaching practices and high summer pumping because of excess irrigation. A more detailed discussion of these drainage patterns in presented in Appendix C4.

Estimated pumping on Bacon Island during the irrigation season was usually quite high, averaging greater than 6 inches per month for 5 months each year. High summer pumping is apparently caused by the water management required for the row crops grown on Bacon Island. Pumping for Bouldin Island in 1990 and for Webb and Holland Tracts in 1990 and 1991 was lower than normal because of reduced agricultural use during levee rehabilitation and participation in the DWR emergency water bank program (Appendix C4).

These available pumping records are quite variable and only provide a rough estimate of the magnitude of the estimated drainage term in the DW project islands agricultural water budget. The variation between years and between islands suggests that the assumed water budgets are simplified representations of actual conditions. This estimated water budget for the DW project islands provides an adequate basis for water supply and environmental impact assessment purposes because the impact assessments are based on the incremental differences between conditions under the No-Project Alternative and those under the DW alternatives.

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Table A1-1. Comparison of Average Annual DWRSIM Inputs and Results with Unimpaired Flow Estimates and Historical Flow Measurements

Location	1922-1991 Period (TAF/yr)					1967-1991 Period (TAF/yr)				
	DWRSIM Input [a]	DWRSIM-Simulated Output [b]	Unimpaired Flow Estimate [c]	Historical Measurement [d]	DAYFLOW Estimate [e]	DWRSIM Input [a]	DWRSIM-Simulated Output [b]	Unimpaired Flow Estimate [c]	Historical Measurement [d]	DAYFLOW Estimate [e]
Upstream Flows										
Trinity River at Lewiston (Clair Engle Reservoir inflows)	1,218		1,245	793		1,334		1,339	314	
Trinity River diversions (J.F. Carr Tunnel)		882		1,061 [f]			1,024		1,027	
Shasta Reservoir inflows	5,555		5,560			5,989		5,985		
Sacramento River at Bend Bridge		8,565	8,067	8,103			9,478	8,721	9,450	
Feather River at Gridley (Oroville Reservoir inflows)	3,889		4,306	3,501 [g]		4,174		4,623	3,468	
Yuba River at Smartville and Bear River at Wheatland	2,899		2,573	2,040 [h]		3,419		2,680	2,018	
American River at Fair Oaks (Folsom Reservoir inflows)	2,700		2,586	2,598		2,847		2,736	2,769	
Sacramento Valley Four-River Index			17,223 [i]					18447		
Delta Flows										
Sacramento River at Freeport		15,998		16,923			17,454		17,280	
Yolo Bypass		2,118			2,752		2,899			3,218
San Joaquin River at Vernalis	2,401		6,017	3,293		3,077		6,669	3,521	
Eastside streams	835		1,067	1,077		1,088		1,157	1,163	
Delta channel depletion	881				923	842				739
Delta exports		5,712		1,688			5,547		4,031	
Delta outflow		14,562			20,616		17,993			20,368

Notes: NA = no data available or not applicable

[a] Flow values used as input to DWRSIM Study 1995-C6B-SWRCB-409.
[b] Simulated output from DWRSIM Study 1995-C6B-SWRCB-409.
[c] Unimpaired flow values from DWR's California Data Exchange Center database.
[d] Historical measured flows from U.S. Geological Survey HYDRODATA database.
[e] DAYFLOW estimates for 1930-1991 by DWR (extended to 1992 by JSA).
[f] Data period is 1963-1991.
[g] Data period is 1965-1991.
[h] Data period is 1942-1991.
[i] Sacramento R. at Bend Bridge + Feather R. + Yuba R. at Smartville + American R. at Fair Oaks.

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Table A1-2. Annual Historical and DWRSIM Inputs for Trinity River and Sacramento River Tributary Flows for Water Years 1922-1991

	A. Historical Flows								B. DWRSIM Inputs						
Water Year	Trinity Unimp. Flow (TAF)	Shasta Unimp. Inflow (TAF)	Carr PP Hist. Flow (TAF)	Red Bluff Unimp. Flow (TAF)	Feather Unimp. Inflow (TAF)	Yuba + Bear Unimp. Flow (TAF)	Amer. R. Unimp. Inflow (TAF)	Four-River Index (TAF)	Clair Engle Inflow (TAF)	Shasta Inflow (TAF)	Carr PP Diversion (TAF)	Red Bluff Flow (TAF)	Oroville Inflow (TAF)	Yuba + Bear Flow (TAF)	Folsom Inflow (TAF)
1922	782	4,636	0	6,702	5,067	3,454	3,290	18,041	759	4,563	765	5,710	4,666	3,723	3,353
1923	686	3,649	0	5,288	3,091	2,463	2,745	13,190	666	3,636	664	6,531	2,838	1,910	2,885
1924	268	2,476	0	3,295	1,301	674	546	5,747	268	2,448	756	5,131	1,412	1,113	902
1925	1,518	5,153	0	8,258	3,124	2,456	2,756	16,296	1,459	5,122	753	6,939	2,707	1,932	2,560
1926	820	3,781	0	5,780	3,139	1,906	1,405	11,961	795	3,764	664	6,220	2,756	1,697	1,728
1927	1,837	7,061	0	11,123	5,749	4,161	3,704	24,167	1,764	6,990	671	10,264	4,934	4,702	3,620
1928	1,056	5,115	0	7,631	4,154	2,737	2,504	16,709	1,025	5,124	674	8,722	3,798	2,841	2,686
1929	528	3,217	0	4,425	1,846	1,136	1,148	8,430	516	3,184	681	5,213	1,781	1,169	1,452
1930	818	4,196	0	6,109	3,949	2,034	1,652	13,529	794	4,152	725	6,100	3,324	2,040	1,576
1931	403	2,540	0	3,300	1,444	715	717	6,104	395	2,537	403	4,451	1,534	979	1,044
1932	716	3,674	0	5,049	3,307	2,355	2,593	13,057	696	3,616	350	5,454	2,790	1,667	2,391
1933	802	3,460	0	4,577	1,994	1,197	1,268	8,915	779	3,441	442	4,454	1,842	1,124	1,520
1934	686	3,333	0	4,522	2,025	1,115	1,129	8,667	668	3,330	349	4,906	1,920	1,121	1,371
1935	970	4,935	0	7,515	4,275	2,603	2,587	16,622	938	4,857	575	6,441	3,536	2,671	2,394
1936	1,026	4,688	0	7,102	4,306	3,028	3,415	17,421	1,001	4,658	517	6,189	3,731	3,600	3,516
1937	996	4,121	0	5,996	3,167	2,195	2,341	13,369	966	4,113	602	6,050	2,703	2,906	2,484
1938	2,105	9,605	0	14,781	8,600	4,617	4,523	31,942	2,017	9,568	664	14,599	7,686	6,042	4,622
1939	572	3,459	0	4,365	1,855	1,026	1,046	8,172	557	3,464	684	6,239	2,072	904	1,453
1940	1,616	7,054	0	10,530	5,687	3,261	3,407	22,487	1,570	7,084	804	10,185	5,019	4,698	3,289
1941	2,549	8,744	0	14,380	6,518	3,638	3,157	27,208	2,438	8,729	1,163	14,381	5,859	4,168	3,275
1942	1,809	7,688	0	11,386	6,694	3,934	3,937	25,442	1,739	7,672	1,559	12,524	6,255	4,459	4,038
1943	1,112	5,884	0	8,509	5,618	3,593	3,869	21,127	1,075	5,883	865	9,013	5,262	3,466	4,028
1944	653	3,680	0	4,700	2,862	1,578	1,457	10,410	636	3,684	728	5,955	2,545	1,634	1,745
1945	1,056	4,902	0	6,773	3,778	2,436	2,551	15,242	1,022	4,881	673	6,326	3,360	2,102	2,528
1946	1,409	5,882	0	8,128	4,166	2,705	2,853	17,538	1,358	5,870	761	8,532	3,758	2,439	2,952
1947	735	3,918	0	5,092	2,547	1,542	1,423	10,433	716	3,914	679	5,779	2,362	1,382	1,714
1948	1,200	5,393	0	7,619	3,840	2,225	2,233	15,696	1,158	5,391	665	6,905	3,262	2,059	2,147
1949	1,094	4,312	0	6,018	2,591	1,697	1,852	11,943	1,057	4,317	714	6,743	2,300	1,484	1,981
1950	855	4,151	0	5,757	3,866	2,508	2,677	14,533	831	4,144	664	5,887	3,434	2,190	2,769
1951	1,617	6,343	0	9,128	5,712	4,143	4,634	23,020	1,556	6,341	761	9,297	5,192	4,829	4,780
1952	1,816	7,781	0	11,528	7,955	4,713	4,965	28,562	1,752	7,818	1,140	11,839	7,236	5,581	5,047
1953	1,612	6,514	0	9,617	5,195	2,803	2,649	20,008	1,549	6,518	1,198	10,369	4,807	2,264	2,827
1954	1,596	6,585	0	9,355	4,248	2,194	2,002	17,531	1,544	6,602	1,375	10,739	3,997	2,187	2,172
1955	734	4,111	0	5,657	2,465	1,454	1,560	10,963	721	4,109	806	6,465	2,292	1,355	1,659
1956	2,014	8,792	0	13,235	7,918	4,475	4,602	29,681	1,939	8,824	1,037	12,958	6,987	4,330	4,638
1957	1,090	5,398	0	7,205	3,651	2,201	2,144	14,970	1,052	5,400	821	7,810	3,527	1,962	2,313
1958	2,731	9,848	0	15,403	7,049	4,063	4,117	30,134	2,610	9,845	1,752	16,430	6,234	4,719	4,175
1959	1,045	5,115	0	6,789	2,868	1,373	1,236	12,139	1,011	5,126	1,022	8,217	2,809	1,645	1,584
1960	1,027	4,737	0	6,476	3,233	1,885	1,686	13,097	1,001	4,764	796	6,744	2,887	1,246	1,613
1961	1,231	5,104	0	7,220	2,653	1,240	1,050	12,055	1,227	5,101	756	7,417	2,302	1,172	1,370
1962	1,053	5,332	0	7,568	3,702	2,202	2,098	15,322	982	5,326	715	7,459	3,187	1,877	1,917
1963	1,612	7,039	700	9,959	6,315	3,744	3,588	23,162	1,594	7,039	947	10,089	5,789	4,545	3,677
1964	795	3,895	1,230	5,204	2,582	1,657	1,629	10,895	739	3,906	926	6,885	2,338	1,634	1,751
1965	1,686	6,964	1,101	10,327	6,878	4,373	4,457	25,519	1,657	6,956	876	9,559	6,123	4,018	4,531
1966	1,345	5,311	1,255	7,304	2,855	1,601	1,393	12,977	1,317	5,331	1,019	8,451	2,705	1,870	1,708
1967	1,653	7,409	1,278	10,517	6,276	3,757	3,957	24,044	1,637	7,390	1,162	10,598	5,634	4,261	3,801
1968	1,019	4,784	1,414	6,933	3,471	1,758	1,709	13,697	1,059	4,827	1,069	8,224	3,331	1,683	1,861
1969	1,750	7,708	1,032	11,880	7,069	4,231	4,449	27,066	1,758	7,707	977	11,961	6,376	5,338	4,462
1970	1,584	7,873	1,366	11,671	6,239	3,264	3,150	23,955	1,563	7,876	1,414	13,187	5,559	5,336	3,419
1971	1,666	7,311	1,212	10,750	5,944	3,239	2,968	22,514	1,683	7,300	1,242	11,049	5,182	3,699	3,057
1972	1,153	5,062	1,174	6,586	3,223	1,874	1,867	13,387	1,175	5,082	972	7,493	2,834	1,883	2,001
1973	1,393	6,200	1,217	9,699	4,750	3,120	3,013	20,125	1,405	6,195	1,071	10,212	4,013	4,670	3,110
1974	2,637	10,765	1,799	15,828	8,332	4,545	4,257	32,383	2,660	10,751	1,999	17,187	7,729	6,039	4,415
1975	1,404	6,426	1,032	9,433	4,862	2,664	2,622	19,298	1,406	6,412	1,057	9,966	4,503	3,271	2,739
1976	669	3,602	1,035	4,747	1,844	727	797	8,053	695	3,600	949	6,479	1,825	1,243	1,145
1977	201	2,634	1,306	3,410	995	390	349	5,124	227	2,624	969	5,529	750	833	449
1978	2,052	7,843	217	12,036	5,682	3,397	3,220	23,920	2,032	7,835	671	9,632	4,780	3,035	2,953
1979	851	4,031	775	5,650	3,024	1,957	2,041	12,442	854	4,034	664	6,495	2,935	2,284	2,193
1980	1,477	6,425	879	9,756	5,537	3,636	3,867	22,344	1,484	6,482	701	9,706	4,840	5,293	3,971
1981	871	4,118	708	6,408	2,488	1,206	1,131	11,132	862	4,109	738	7,324	2,365	1,463	1,402
1982	2,027	9,059	1,095	13,341	9,051	5,702	6,164	33,513	1,996	9,060	1,134	13,508	8,284	8,534	6,164
1983	2,989	10,835	1,694	17,258	9,440	5,428	6,387	37,801	2,887	10,837	1,792	18,879	8,880	6,920	6,540
1984	1,550	6,633	1,206	9,464	5,738	3,522	3,884	22,234	1,516	6,654	1,432	10,746	5,320	5,530	4,147
1985	841	3,971	673	5,518	2,650	1,475	1,581	11,074	841	3,977	992	7,270	2,585	1,494	1,790
1986	1,616	7,694	904	11,168	6,904	4,108	4,707	26,341	1,602	7,696	808	11,158	6,199	5,260	4,669
1987	883	3,952	606	5,290	2,182	938	884	9,237	870	3,951	845	6,920	1,733	1,294	1,097
1988	939	3,909	964	5,375	1,996	989	850	9,135	936	3,925	765	6,677	1,885	982	953
1989	1,060	4,727	786	6,594	3,682	2,483	2,240	14,735	1,045	4,740	771	5,936	3,164	2,319	2,149
1990	716	3,605	628	4,723	2,142	1,322	1,120	9,219	687	3,607	693	5,754	1,831	1,386	1,335
1991	486	3,051	664	3,991	2,058	1,276	1,184	8,403	463	3,046	719	5,070	1,811	1,429	1,363
Average															
'22 - '91	1,245	5,560	1,061	8,067	4,306	2,573	2,586	17,223	1,218	5,555	882	8,565	3,889	2,899	2,700
'67 - '91	1,339	5,985	1,027	8,721	4,623	2,680	2,736	18,447	1,334	5,989	1,024	9,478	4,174	3,419	2,847

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Table A1–3. Historical and DWRSIM–Simulated Carryover Storage for Water Years 1922–1991

A. Historical Carryover

Water Year	Clair Engle Storage (TAF)	Shasta Storage (TAF)	Oroville Storage (TAF)	Folsom Storage (TAF)	San Luis Storage (TAF)	New Melones Storage (TAF)
1922						
1923						
1924						
1925						
1926						
1927						
1928						
1929						
1930						
1931						
1932						
1933						
1934						
1935						
1936						
1937						
1938						
1939						
1940						
1941						
1942						
1943						
1944						
1945						
1946						
1947						
1948						
1949						
1950						
1951						
1952						
1953						
1954		3,057				
1955		2,455				
1956		3,569		533		
1957		3,485		535		
1958		3,473		550		
1959		2,504		312		
1960		2,756		518		
1961		2,333		389		
1962	1,793	2,908		454		
1963	2,196	3,242		466		
1964	1,559	2,202		536		
1965	1,997	3,612		671		
1966	1,880	3,263		653		
1967	1,969	3,506		799		
1968	1,388	2,670	1,678	551		
1969	1,905	3,528	2,780	814	1,981	
1970	1,871	3,440	2,542	549	1,720	
1971	2,106	3,275	2,730	686	1,736	
1972	1,913	3,267	2,612	659	1,482	
1973	1,904	3,317	2,729	742	1,691	
1974	1,996	3,658	2,397	773	1,852	
1975	2,041	3,570	2,858	773	1,032	
1976	1,503	1,295	1,828	416	678	3
1977	242	631	915	147	274	3
1978	1,870	3,428	2,744	700	1,719	44
1979	1,661	3,141	2,672	710	1,213	116
1980	1,879	3,321	2,611	670	1,483	277
1981	1,702	2,480	2,354	600	263	124
1982	2,115	3,486	2,775	756	23	1,358
1983	2,164	3,617	2,818	752	1,940	2,024
1984	1,889	3,240	2,529	681	812	1,841
1985	1,762	1,978	2,132	587	763	1,508
1986	1,901	3,211	2,661	653	1,481	1,948
1987	1,813	2,108	1,979	430	688	1,443
1988	1,479	1,586	1,529	218	488	989
1989	1,376	2,096	2,150	571	365	672
1990	1,162	1,637	1,163	178	488	378
1991	670	1,340	1,399	506	654	296
Average						
'22 – '91	1,724	2,834	2,274	571	1,079	814
'67 – '91	1,691	2,753	2,274	597	1,079	814

B. DWRSIM–Simulated Carryover

Water Year	Clair Engle Storage (TAF)	Shasta Storage (TAF)	Oroville Storage (TAF)	Folsom Storage (TAF)	San Luis Storage (TAF)	New Melones Storage (TAF)
1922	1,694	3,700	3,303	841	621	1,305
1923	1,343	2,780	2,279	461	431	1,091
1924	491	1,277	868	99	129	721
1925	864	2,781	1,072	465	365	584
1926	642	2,503	908	156	371	396
1927	1,421	3,563	3,003	759	556	890
1928	1,429	2,706	1,851	291	469	1,055
1929	909	2,235	1,073	115	151	831
1930	634	2,516	1,534	370	452	721
1931	280	1,560	1,064	100	229	473
1932	295	1,141	1,574	738	437	765
1933	301	1,365	1,281	291	211	580
1934	282	1,169	984	100	212	300
1935	313	2,225	1,524	314	564	635
1936	462	3,047	2,576	653	555	586
1937	498	3,257	2,699	643	573	521
1938	1,560	3,700	3,350	925	1,203	1,837
1939	1,078	2,203	1,715	99	327	1,496
1940	1,511	2,976	1,956	545	454	1,458
1941	2,194	3,700	3,348	882	960	1,761
1942	2,068	3,700	3,344	906	920	1,823
1943	1,929	3,568	2,896	744	571	1,749
1944	1,479	2,616	2,238	388	364	1,366
1945	1,478	3,222	2,487	643	384	1,321
1946	1,753	3,079	2,196	569	496	1,030
1947	1,434	2,640	1,304	291	394	641
1948	1,597	3,619	1,449	708	283	651
1949	1,601	3,131	1,041	542	404	548
1950	1,419	3,140	1,286	683	299	419
1951	1,888	3,253	2,250	614	395	683
1952	2,091	3,700	3,350	961	1,595	1,742
1953	2,115	3,700	3,291	824	723	1,548
1954	1,956	3,242	1,976	413	534	1,222
1955	1,518	2,814	1,056	329	476	842
1956	2,062	3,700	3,113	919	957	1,397
1957	1,941	3,486	2,181	580	458	1,137
1958	2,117	3,700	3,350	935	1,353	1,741
1959	1,761	2,857	2,035	285	419	1,320
1960	1,615	2,923	1,459	273	412	1,008
1961	1,739	2,997	954	269	414	696
1962	1,668	3,314	1,201	547	414	440
1963	2,001	3,700	2,873	750	651	886
1964	1,473	2,540	1,835	171	467	719
1965	1,965	3,700	2,518	776	603	800
1966	1,943	3,108	1,962	349	453	654
1967	2,093	3,700	3,350	940	1,643	1,601
1968	1,759	3,112	2,069	319	401	1,267
1969	2,050	3,700	3,162	915	1,519	2,273
1970	1,909	3,165	2,333	474	420	1,532
1971	2,057	3,700	2,904	850	667	1,364
1972	1,935	3,337	1,870	456	438	1,053
1973	1,958	3,470	2,418	580	603	952
1974	2,088	3,700	3,338	934	1,096	1,136
1975	2,078	3,700	3,135	877	918	1,079
1976	1,483	2,612	2,225	171	542	785
1977	393	1,072	771	59	654	459
1978	1,476	3,700	3,327	786	775	917
1979	1,335	3,240	2,591	521	578	806
1980	1,795	3,700	3,118	834	871	1,755
1981	1,546	2,938	1,972	257	361	1,436
1982	2,056	3,700	3,351	966	1,469	2,273
1983	2,263	3,700	3,351	975	1,821	2,273
1984	2,015	3,700	2,824	668	686	1,758
1985	1,488	2,648	1,771	260	404	1,618
1986	1,900	3,256	2,731	722	695	2,118
1987	1,558	2,234	1,429	99	366	1,695
1988	1,358	1,460	904	100	124	1,309
1989	1,274	2,567	1,180	320	378	1,144
1990	902	1,971	965	100	153	814
1991	300	1,413	1,143	175	164	591
Average						
'22 – '91	1,484	2,962	2,141	524	592	1,120
'67 – '91	1,643	3,020	2,329	534	710	1,360

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Table A1–4. Annual Historical and DWRSIM–Simulated Delta Inflows for Water Years 1922–1991

	A. Historical Flows					B. DWRSIM–Simulated Flows				
Water Year	Freeport Historical Flow (TAF)	Yolo Bypass Historical Flow (TAF)	Vernalis Historical Flow (TAF)	Eastside Historical Flow (TAF)	Delta Rainfall (TAF)	Sacto. R. Inflow (TAF)	Yolo Bypass Inflow (TAF)	SJR Inflow (TAF)	Eastside Inflow (TAF)	Total River Inflows (TAF)
1922	18,998	1,302	6,732	1,840	548	15,237	202	3,037	1,038	19,514
1923	13,989	0	4,043	1,440	562	14,489	194	2,491	816	17,990
1924	4,373	0	486	106	146	8,586	69	1,259	201	10,116
1925	15,363	2,485	3,749	1,474	626	12,064	809	1,462	630	14,965
1926	11,747	721	1,939	461	446	11,614	344	1,511	390	13,858
1927	23,001	5,200	5,076	1,641	599	19,015	3,222	1,892	724	24,853
1928	16,199	2,092	2,709	1,034	432	18,455	991	1,706	577	21,730
1929	7,472	0	937	266	288	8,696	100	1,304	299	10,398
1930	13,190	906	1,266	466	607	10,768	164	1,140	329	12,400
1931	5,148	36	678	159	523	6,775	68	1,255	205	8,303
1932	12,218	432	3,669	930	731	8,618	157	1,655	586	11,016
1933	7,722	64	1,383	418	531	7,535	83	1,388	264	9,270
1934	8,041	228	928	432	558	8,173	146	1,201	304	9,824
1935	16,043	2,072	4,034	1,043	765	12,496	1,209	2,051	637	16,394
1936	15,512	3,357	4,986	1,602	984	13,335	1,413	2,141	1,059	17,949
1937	13,670	1,228	5,510	1,231	958	12,426	246	2,804	940	16,416
1938	25,878	14,152	10,879	2,188	1,002	28,179	8,591	5,428	1,662	43,860
1939	7,080	170	1,714	422	581	10,712	70	1,695	286	12,763
1940	18,267	6,974	4,765	1,340	948	17,638	4,572	1,896	756	24,862
1941	23,698	11,510	7,310	1,292	1,026	23,780	9,163	3,677	809	37,429
1942	22,795	6,733	6,188	1,565	1,121	25,353	5,099	2,986	1,154	34,592
1943	19,660	3,145	6,079	1,826	1,044	20,972	1,639	3,151	1,550	27,313
1944	9,069	124	1,798	515	751	11,388	191	1,642	394	13,615
1945	13,155	735	4,446	1,185	837	12,566	335	2,244	745	15,891
1946	15,903	2,101	3,627	1,091	748	16,177	1,462	2,071	795	20,506
1947	9,491	72	1,334	369	510	10,949	109	1,557	291	12,905
1948	14,552	301	1,550	703	660	13,098	41	1,418	364	14,921
1949	11,793	260	1,242	613	636	11,993	193	1,423	455	14,065
1950	13,948	357	1,796	993	606	12,811	111	1,532	508	14,962
1951	21,766	3,445	4,735	2,321	927	21,672	1,900	2,583	1,790	27,945
1952	28,056	3,945	7,136	2,477	1,096	28,323	2,379	3,023	1,770	35,496
1953	18,121	2,752	1,893	859	660	18,839	2,492	1,965	533	23,828
1954	17,110	1,213	1,713	717	589	19,873	746	1,572	368	22,559
1955	10,591	76	978	557	788	11,447	172	1,365	435	13,419
1956	22,328	9,860	6,287	2,359	1,159	21,768	8,268	3,270	1,485	34,792
1957	13,150	778	1,440	684	759	15,092	399	1,785	412	17,688
1958	26,058	10,012	6,059	2,396	1,573	26,266	8,873	3,396	1,657	40,193
1959	12,059	635	1,249	366	794	14,716	383	1,732	339	17,170
1960	10,771	618	550	255	559	11,339	317	1,217	304	13,177
1961	11,488	169	438	103	713	11,459	206	1,139	216	13,021
1962	13,089	1,123	1,505	683	820	12,372	711	1,484	460	15,027
1963	20,422	4,170	2,839	1,334	1,247	20,611	2,943	1,934	741	26,229
1964	11,591	67	1,119	307	643	12,397	148	1,358	315	14,218
1965	19,965	6,193	3,803	1,644	926	19,519	4,554	2,323	1,222	27,618
1966	13,392	377	1,698	639	686	13,901	319	1,962	399	16,582
1967	24,233	3,661	5,559	1,723	1,294	22,181	2,615	3,304	1,298	29,398
1968	13,377	668	1,423	520	653	15,971	709	1,660	432	18,772
1969	23,362	6,281	10,168	2,391	1,260	23,660	5,750	5,442	1,935	36,787
1970	20,289	8,500	3,076	1,415	895	21,543	8,061	3,283	1,196	34,082
1971	22,811	1,306	1,779	902	941	20,939	1,152	1,732	707	24,531
1972	12,470	30	1,112	365	437	13,210	192	1,515	357	15,275
1973	20,758	3,887	2,392	1,429	1,244	19,810	3,467	2,175	1,161	26,612
1974	30,663	7,566	2,773	1,551	995	29,264	7,121	2,238	1,255	39,878
1975	19,941	951	2,826	1,125	828	20,440	920	2,310	894	24,564
1976	10,963	15	1,523	206	460	10,456	86	1,160	220	11,923
1977	5,497	1	416	30	445	6,824	105	1,016	149	8,095
1978	17,691	2,844	4,490	1,146	1,368	16,859	2,457	2,267	840	22,423
1979	13,034	154	2,625	1,020	941	13,993	130	2,300	688	17,112
1980	19,248	6,502	5,986	1,830	1,045	18,292	5,602	4,818	1,325	30,037
1981	11,499	126	1,763	286	725	13,093	110	1,912	343	15,457
1982	30,101	7,229	5,477	3,038	1,655	29,591	6,745	5,387	3,093	44,815
1983	34,049	14,962	15,438	4,557	1,713	35,577	13,561	15,726	4,914	69,778
1984	22,384	4,689	6,260	1,807	863	23,213	4,153	6,450	2,167	35,984
1985	12,192	172	2,101	470	743	13,038	192	1,859	459	15,548
1986	18,112	10,608	5,235	2,124	1,454	18,958	8,880	4,814	2,385	35,036
1987	10,031	35	1,808	384	683	10,952	78	1,645	337	13,012
1988	9,653	115	1,164	143	718	9,416	137	1,014	242	10,810
1989	12,244	44	1,057	221	795	11,782	80	1,006	323	13,190
1990	9,860	21	914	169	619	8,675	100	940	215	9,930
1991	7,540	75	655	221	847	8,612	76	958	269	9,915
Average										
'22 – '91	16,923	2,752	3,293	1,077	819	15,998	2,118	2,401	835	21,351
'67 – '91	17,280	3,218	3,521	1,163	945	17,454	2,899	3,077	1,088	24,518

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Table A1–5. Annual Historical and DWRSIM–Simulated Delta Outflows and Exports for Water Years 1922–1991

	A. Historical Flows						B. DWRSIM–Simulated Flows						
Water Year	Net Channel Depletion (TAF)	CCWD Exports (TAF)	CVP Exports (TAF)	SWP Exports (TAF)	CVP + SWP Exports (TAF)	Delta Outflow (TAF)	Net Channel Depletion (TAF)	CCWD Exports (TAF)	CVP Exports (TAF)	SWP Exports (TAF)	CVP + SWP Exports (TAF)	Delta Outflow (TAF)	WQCP Required Outflow (TAF)
1922	877					28,798	835	144	3,049	3,136	6,185	12,296	6,103
1923	863					19,471	823	144	2,893	3,298	6,191	10,778	5,833
1924	1,279					4,965	1,223	151	2,363	2,179	4,542	4,155	4,063
1925	799					23,071	762	153	2,923	2,812	5,735	8,267	5,195
1926	979					14,868	937	144	2,827	2,907	5,734	6,997	5,006
1927	826					34,918	786	144	3,025	3,217	6,242	17,631	6,980
1928	993					22,033	953	144	2,987	3,341	6,327	14,252	6,665
1929	1,137					8,675	1,094	151	2,234	2,330	4,564	4,548	4,418
1930	804					15,017	981	153	2,373	2,636	5,009	6,220	5,052
1931	881					5,132	1,113	151	1,900	1,427	3,327	3,677	3,657
1932	669					16,577	838	160	2,274	1,874	4,148	5,825	5,190
1933	868					8,706	1,103	160	1,877	1,801	3,678	4,288	4,050
1934	842					8,786	1,065	160	1,907	1,829	3,737	4,829	4,532
1935	633					22,551	817	153	2,861	3,064	5,925	9,453	6,455
1936	416					25,057	745	144	2,962	3,191	6,154	10,852	6,248
1937	443					21,206	699	144	2,997	2,881	5,879	9,641	5,287
1938	399					52,716	520	144	3,020	3,207	6,227	36,915	8,125
1939	831					8,551	1,148	144	2,532	2,556	5,089	6,328	4,357
1940	481					30,867	593	144	3,045	3,375	6,420	17,651	7,246
1941	417					43,400	453	144	2,981	3,294	6,275	30,503	7,010
1942	335					36,944	700	144	3,038	2,912	5,949	27,744	6,671
1943	428					30,287	830	144	3,034	2,524	5,558	20,726	7,309
1944	737					10,772	993	144	2,807	3,122	5,928	6,496	4,952
1945	686					18,843	920	144	2,960	3,174	6,134	8,640	5,277
1946	805					21,908	1,023	144	2,936	3,355	6,290	12,995	6,279
1947	1071					10,189	1,116	144	2,795	3,238	6,033	5,558	5,072
1948	951					16,145	1,038	144	2,909	3,391	6,301	7,384	5,487
1949	991					12,597	1,065	144	2,839	2,853	5,692	7,117	4,921
1950	1036	21				15,236	1,063	144	2,928	3,223	6,151	7,554	5,599
1951	718	30	161		162	30,552	770	144	2,981	3,785	6,766	20,212	6,326
1952	550	30	164		165	40,375	611	144	3,090	3,836	6,927	27,761	7,985
1953	963	34	778		787	22,362	976	144	2,779	2,525	5,304	17,350	6,080
1954	1049	42	1,004		1,020	19,140	1,104	144	2,993	3,380	6,373	14,884	7,021
1955	848	47	1,113		1,128	10,040	974	144	2,694	3,322	6,016	6,230	5,051
1956	527	44	721		721	39,743	638	144	3,008	3,816	6,824	27,133	6,221
1957	925	54	1,180		1,180	13,920	1,034	144	2,836	3,450	6,286	10,171	5,661
1958	111	48	657		657	43,765	383	144	3,156	3,891	7,047	32,566	7,267
1959	890	68	1,336		1,336	12,039	1,065	144	2,589	2,588	5,176	10,730	5,294
1960	1127	76	1,384		1,384	9,707	1,085	144	2,761	3,095	5,856	6,038	5,203
1961	971	78	1,483		1,483	9,687	1,053	144	2,698	3,078	5,776	5,995	5,097
1962	864	72	1,350		1,350	14,139	923	144	2,800	2,996	5,797	8,109	5,063
1963	437	62	1,338		1,338	26,969	698	144	3,113	3,539	6,652	18,682	7,329
1964	1044	82	1,644		1,644	10,384	1,124	144	2,649	3,265	5,914	6,983	5,143
1965	759	72	1,467		1,467	29,347	883	144	2,984	3,667	6,651	19,887	6,670
1966	999	84	1,593		1,593	13,449	1,042	144	2,830	3,572	6,402	8,940	5,602
1967	390	72	1,252		1,252	33,515	562	144	3,056	3,809	6,865	21,774	7,553
1968	1033	96	1,995	473	2,468	12,507	1,038	144	2,498	2,284	4,783	12,753	5,557
1969	424	78	1,844	1,031	2,875	38,883	616	144	3,079	3,350	6,430	29,543	7,967
1970	789	94	1,652	416	2,067	30,290	842	144	2,569	2,462	5,031	28,011	5,637
1971	743	75	1,917	913	2,830	23,191	906	144	3,093	3,720	6,813	16,614	7,094
1972	1249	104	2,348	1,093	3,441	9,261	1,178	144	2,815	3,528	6,343	7,556	5,409
1973	440	93	1,846	1,518	3,364	24,609	454	144	2,971	3,637	6,608	19,352	6,821
1974	689	79	2,445	1,915	4,360	37,482	793	144	3,174	3,654	6,829	32,058	6,944
1975	856	79	2,353	1,552	3,904	20,043	922	144	2,986	3,508	6,494	16,950	6,627
1976	1226	111	3,013	1,827	4,839	6,583	1,218	151	2,367	2,631	4,999	5,503	4,416
1977	1239	99	1,281	797	2,078	2,539	1,193	160	1,658	1,394	3,053	3,657	3,657
1978	316	77	2,270	2,080	4,350	21,467	517	153	2,569	1,938	4,507	17,204	7,933
1979	743	91	2,287	2,182	4,470	11,555	860	144	2,915	2,890	5,804	10,250	5,844
1980	641	87	2,007	2,516	4,523	28,501	667	144	2,847	2,827	5,673	23,499	6,568
1981	960	107	2,591	2,130	4,722	7,908	1,085	144	2,795	2,793	5,588	8,587	5,109
1982	30	75	1,976	2,644	4,621	41,230	403	144	3,150	4,116	7,266	36,948	7,099
1983	–29	79	2,505	1,894	4,399	64,643	51	144	2,783	2,631	5,414	64,112	6,197
1984	824	98	2,194	1,647	3,841	30,592	950	144	2,406	2,170	4,576	30,259	5,676
1985	941	113	2,791	2,680	5,471	8,453	940	144	2,768	3,166	5,934	8,477	5,068
1986	230	110	2,619	2,667	5,286	30,493	492	144	2,846	3,422	6,268	28,078	6,155
1987	1001	131	2,760	2,283	5,043	6,105	1,119	144	2,739	3,069	5,808	5,888	4,819
1988	968	135	2,897	2,714	5,611	4,409	1,034	144	2,296	2,150	4,446	5,143	4,505
1989	889	134	2,870	3,097	5,967	6,599	1,081	144	2,601	2,677	5,278	6,644	4,816
1990	1060	136	2,703	3,109	5,811	3,967	1,065	151	2,321	1,744	4,065	4,615	4,506
1991	834	106	1,409	1,771	3,180	4,371	1,065	160	2,493	1,315	3,808	4,853	4,088
Average													
'22 – '91	768	81	1,785	1,873	2,883	20,616	881	146	2,758	2,955	5,712	14,562	5,802
'67 – '91	739	98	2,233	1,873	4,031	20,368	842	146	2,712	2,835	5,547	17,933	5,843

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Table A1–6. Estimated Acreage of Delta Land Use Categories

Land Use Area	Land Use Category	Area (acres)
Delta Uplands (DWR Depletion Study)	Open Water	6,000
	Riparian	2,000
	Urban	15,700
	Irrigated Crops	142,500
	Natural and Idle	49,900
	Total	216,100
Delta Lowlands (DWR Depletion Study)	Open Water	48,000
	Riparian	7,000
	Urban	10,500
	Irrigated Crops	342,400
	Natural and Idle	54,200
	Total	462,100
DW Reservoir Islands (Bacon and Webb Tract)	Total	11,008
DW Habitat Islands (Bouldin Island and Holland Tract)	Riparian–Marsh–Water	1,102
	Upland–Developed	1,077
	Irrigated Crops	3,046
	Seasonal Wetlands	3,895
	Total	9,120

Notes: DWR depletion analysis based on Bulletin 160–83 land use projections for 1995 level of development (DWR 1983).
DW reservoir and habitat islands are included in Delta lowlands for No–Project Alternative conditions.

Table A1-7. Estimated Monthly Water Budget Terms for the Delta

	Monthly Amount (inches)												Annual Total (inches)	Contributing Area (acres)	Annual Volume (TAF)
	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP			
Water, Riparian, and Urban Area															
Rainfall	0.8	2.2	2.6	3.2	2.5	2.7	1.2	0.4	0.1	0.1	0.1	0.4	16.3	89,200	121
Water evaporation	3.7	1.7	0.9	1.0	1.9	3.4	5.1	6.9	7.9	9.0	8.0	5.9	55.4	63,000	291
Irrigated Delta Uplands Area															
Rainfall	0.8	2.2	2.6	3.2	2.5	2.7	1.2	0.4	0.1	0.1	0.1	0.4	16.3	142,500	194
Soil moisture	2.0	3.0	4.0	4.0	4.0	4.0	2.5	2.0	2.0	2.0	2.0	2.0	33.5		
Uplands evapotranspiration	1.8	1.2	0.6	0.7	1.5	2.1	2.7	4.1	5.6	6.9	5.4	3.3	36.0	142,500	427
Applied water	2.1	0.0	0.0	0.0	0.0	0.0	0.0	6.5	11.1	13.6	10.6	5.7	49.6	142,500	589
Drainage water	1.0	0.0	1.0	2.5	1.0	0.6	0.0	3.3	5.5	6.8	5.3	2.9	29.9	142,500	355
Irrigated Delta Lowlands Area															
Rainfall	0.8	2.2	2.6	3.2	2.5	2.7	1.2	0.4	0.1	0.1	0.1	0.4	16.3	342,400	465
Soil moisture	4.0	5.1	7.1	8.0	8.0	8.0	6.5	4.0	4.0	4.0	4.0	4.0			
Lowlands evapotranspiration	1.4	1.1	0.6	0.7	1.5	2.1	2.7	3.8	4.9	5.8	4.3	2.3	31.2	342,400	890
Seepage	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	12.0	342,400	342
Salt leaching water	0.0	0.0	2.0	2.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	342,400	171
Applied water	1.2	0.0	0.0	0.0	0.0	0.0	0.0	1.9	9.5	11.3	8.3	3.9	36.1	342,400	1,030
Drainage water	1.6	1.0	1.0	4.6	4.0	3.6	1.0	1.9	5.8	6.7	5.2	2.9	39.2	342,400	1,119

Notes: Flooded depth is assumed to average 1 foot.
Drainage is assumed to be at least 50% of previous month's flooded volume for circulation.
Long-term average monthly rainfall is assumed; variations from year to year will occur.
Soil moisture is assumed to supply water for evapotranspiration or store excess rainfall.
The soil moisture from the previous month plus the rainfall plus the seepage plus the applied water minus the ET minus the end-of-month soil moisture will equal the drainage.

C-061226

Table A1–8. Estimated Monthly Water Budget Terms for DW Islands

	Month												Annual Total (inches)	Contributing Area (acres)	Annual Volume (TAF)
	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP			
DW Project Islands Intensified Agricultural Use															
Rainfall (inches)	0.8	2.2	2.6	3.2	2.5	2.7	1.2	0.4	0.1	0.1	0.1	0.4	16.3	17,000	23
Soil moisture (inches)	4.0	5.1	7.1	8.0	8.0	8.0	6.5	4.0	4.0	4.0	4.0	4.0			
Lowlands evapotranspiration (inches)	1.4	1.1	0.6	0.7	1.5	2.1	2.7	3.8	4.9	5.8	4.3	2.3	31.2	17,000	44
Seepage (inches)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	12.0	17,000	17
Salt leaching water (inches)	0.0	0.0	2.0	2.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	17,000	9
Applied water (inches)	1.2	0.0	0.0	0.0	0.0	0.0	0.0	1.9	9.5	11.3	8.3	3.9	36.1	17,000	51
Drainage water (inches)	1.6	1.0	1.0	4.6	4.0	3.6	1.0	1.9	5.8	6.7	5.2	2.9	39.2	17,000	56
DW Project Islands Wildlife Habitat Use															
Water and marsh (acres)	1,060	1,060	1,060	1,060	1,060	1,060	1,060	1,060	1,060	1,060	1,060	1,060			
Flooded area (acres)	2,000	3,400	5,000	4,500	4,300	1,400	500	0	0	0	0	1,200			
Irrigated area (acres)	5,000	3,600	2,000	2,500	2,700	5,600	6,500	7,000	7,000	7,000	7,000	5,800			
Rainfall (inches)	0.8	2.2	2.6	3.2	2.5	2.7	1.2	0.4	0.1	0.1	0.1	0.4	16.3		
Water evaporation (inches)	3.7	1.7	0.9	1.0	1.9	3.4	5.1	6.9	7.9	9.0	8.0	5.9	55.4		
Lowlands evapotranspiration (inches)	1.4	1.1	0.6	0.7	1.5	2.1	2.7	3.8	4.9	5.8	4.3	2.3	31.2		
Soil moisture	4.0	5.1	7.1	8.0	8.0	8.0	6.5	4.0	4.0	4.0	4.0	4.0			
Seepage volume (TAF)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5			6
Change in flooded volume (TAF)	0.8	1.4	1.6	(0.5)	(0.2)	(2.9)	(0.9)	(0.5)	0.0	0.0	0.0	1.2			0
Net evaporation (TAF)	1.0	(0.2)	(0.9)	(1.3)	(0.5)	(0.1)	0.5	1.1	3.5	4.1	3.1	2.0			12
Applied water (TAF)	1.9	1.7	1.9	0.2	1.1	0.0	0.0	0.4	3.0	3.6	2.6	2.7			19
Drainage water (TAF)	0.6	1.0	1.7	2.5	2.3	2.2	0.7	0.3	0.0	0.0	0.0	0.0			11

Notes: Flooded depth is assumed to average 1 foot.
Drainage is assumed to be at least 50% of previous month's flooded volume for circulation.
Long–term average monthly rainfall is assumed; variations from year to year will occur.
Soil moisture is assumed to supply water for evapotranspiration or store excess rainfall.
Rainfall plus seepage plus applied water minus the change in soil moisture minus evaporation minus ET will equal the drainage.

C–061227

Table A1–9. DW Project Islands Drainage Pumping Estimates for 1986–1992 based on PG&E Pumping Tests (af/kWh) and Power Consumption Records

Water Year	Month	Bouldin Island 5,985 acres (AF)	Bouldin Island 5,985 acres (inches)	Bacon Island 5,539 acres (AF)	Bacon Island 5,539 acres (inches)	Webb Tract 5,469 acres (AF)	Webb Tract 5,469 acres (inches)	Holland Tract 4,187 acres (AF)	Holland Tract 4,187 acres (inches)
1986	OCT	87	0.2						
	NOV	2,217	4.4						
	DEC	3,387	6.8						
	JAN	2,125	4.3						
	FEB	2,771	5.6						
	MAR	3,944	7.9						
	APR	558	1.1						
	MAY	1,292	2.6						
	JUN	1,553	3.1						
	JUL	2,688	5.4						
	AUG	2,939	5.9						
	SEP	1,102	2.2						
1987	OCT	245	0.5						
	NOV	1,932	3.9						
	DEC	3,419	6.9						
	JAN	2,074	4.2						
	FEB	3,736	7.5						
	MAR	1,377	2.8						
	APR	837	1.7						
	MAY	909	1.8						
	JUN	804	1.6						
	JUL	1,113	2.2						
	AUG	1,740	3.5						
	SEP	1,125	2.3						
1988	OCT	621	1.2	1,834	4.0				
	NOV	1,248	2.5	655	1.4				
	DEC	1,785	3.6	3,243	7.0				
	JAN	2,701	5.4	2,185	4.7				
	FEB	574	1.2	590	1.3				
	MAR	501	1.0	721	1.6				
	APR	758	1.5	1,852	4.0				
	MAY	378	0.8	2,981	6.5				
	JUN	542	1.1	1,506	3.3				
	JUL	1,064	2.1	5,624	12.2				
	AUG	780	1.6	4,679	10.1				
	SEP	54	0.1	3,412	7.4				
1989	OCT	449	0.9	2,085	4.5				
	NOV	1,177	2.4	216	0.5				
	DEC	2,960	5.9	1,042	2.3				
	JAN	3,929	7.9	4,265	9.2				
	FEB	690	1.4	2,292	5.0				
	MAR	272	0.5	1,294	2.8				
	APR	647	1.3	1,755	3.8				
	MAY	702	1.4	4,091	8.9				
	JUN	1,451	2.9	4,309	9.3				
	JUL	2,072	4.2	3,486	7.6				
	AUG	1,775	3.6	3,618	7.8				
	SEP	408	0.8	3,932	8.5				

Table A1-9. Continued

Water Year	Month	Bouldin Island 5,985 acres (AF)	(inches)	Bacon Island 5,539 acres (AF)	(inches)	Webb Tract 5,469 acres (AF)	(inches)	Holland Tract 4,187 acres (AF)	(inches)
1990	OCT	81	0.2	1,520	3.3	0	0.0	216	0.6
	NOV	304	0.6	923	2.0	36	0.1	269	0.8
	DEC	51	0.1	3,843	8.3	46	0.1	840	2.4
	JAN	1,226	2.5	2,286	5.0	1,545	3.4	525	1.5
	FEB	486	1.0	1,698	3.7	830	1.8	506	1.4
	MAR	757	1.5	972	2.1	733	1.6	477	1.3
	APR	1,376	2.8	1,594	3.5	733	1.6	473	1.3
	MAY	458	0.9	2,938	6.4	730	1.6	488	1.4
	JUN	367	0.7	3,640	7.9	81	0.2	301	0.9
	JUL	1,169	2.3	3,380	7.3	188	0.4	146	0.4
	AUG	821	1.6	3,532	7.7	188	0.4	171	0.5
	SEP	138	0.3	4,079	8.8	85	0.2	124	0.4
1991	OCT	798	1.6	1,465	3.2	233	0.5	218	0.6
	NOV	2,596	5.2	897	1.9	1,230	2.7	722	2.0
	DEC	2,596	5.2	5,316	11.5	2,223	4.9	549	1.6
	JAN	1,873	3.8	2,197	4.8	2,042	4.5	1,317	3.7
	FEB	1,831	3.7	1,845	4.0	1,487	3.3	1,701	4.8
	MAR	1,831	3.7	1,281	2.8	1,360	3.0	544	1.5
	APR	368	0.7	786	1.7	245	0.5	160	0.5
	MAY	158	0.3	4,268	9.2	78	0.2	157	0.4
	JUN	724	1.5	4,153	9.0	80	0.2	293	0.8
	JUL	1,650	3.3	4,153	9.0	52	0.1	64	0.2
	AUG	2,757	5.5	4,995	10.8	44	0.1	675	1.9
	SEP	65	0.1	3,940	8.5	69	0.2	347	1.0
1992	OCT	128	0.3	1,424	3.1	203	0.4	284	0.8
	NOV	1,547	3.1	442	1.0	788	1.7	232	0.7
	DEC	1,940	3.9	4,051	8.8	1,871	4.1	290	0.8
	JAN	1,811	3.6	1,936	4.2	1,891	4.1	616	1.7
	FEB	3,287	6.6	1,826	4.0	1,279	2.8	1,001	2.8
	MAR	3,287	6.6	1,826	4.0	2,699	5.9	906	2.6
	APR	264	0.5	1,275	2.8	2,349	5.2	508	1.4
	MAY	122	0.2	5,147	11.2	456	1.0	359	1.0
	JUN	1,061	2.1	4,295	9.3	291	0.6	391	1.1
	JUL	1,614	3.2	2,486	5.4	416	0.9	436	1.2
	AUG	1,245	2.5	3,433	7.4	582	1.3	430	1.2
	SEP	1,250	2.5	3,807	8.2	413	0.9	287	0.8
Annual Totals									
1986		24,663	49						
1987		19,311	39						
1988		11,006	22	29,282	63				
1989		16,532	33	32,385	70				
1990		7,234	15	30,405	66	5,195	11	4,536	13
1991		17,247	35	35,296	76	9,143	20	6,747	19
1992		17,556	35	31,948	69	13,238	29	5,740	16
Average		16,221	33	31,863	69	9,192	20	5,674	16

Combined DW Islands (21,180 acres)

Annual Pumping (inches)	1990	27
	1991	39
	1992	39

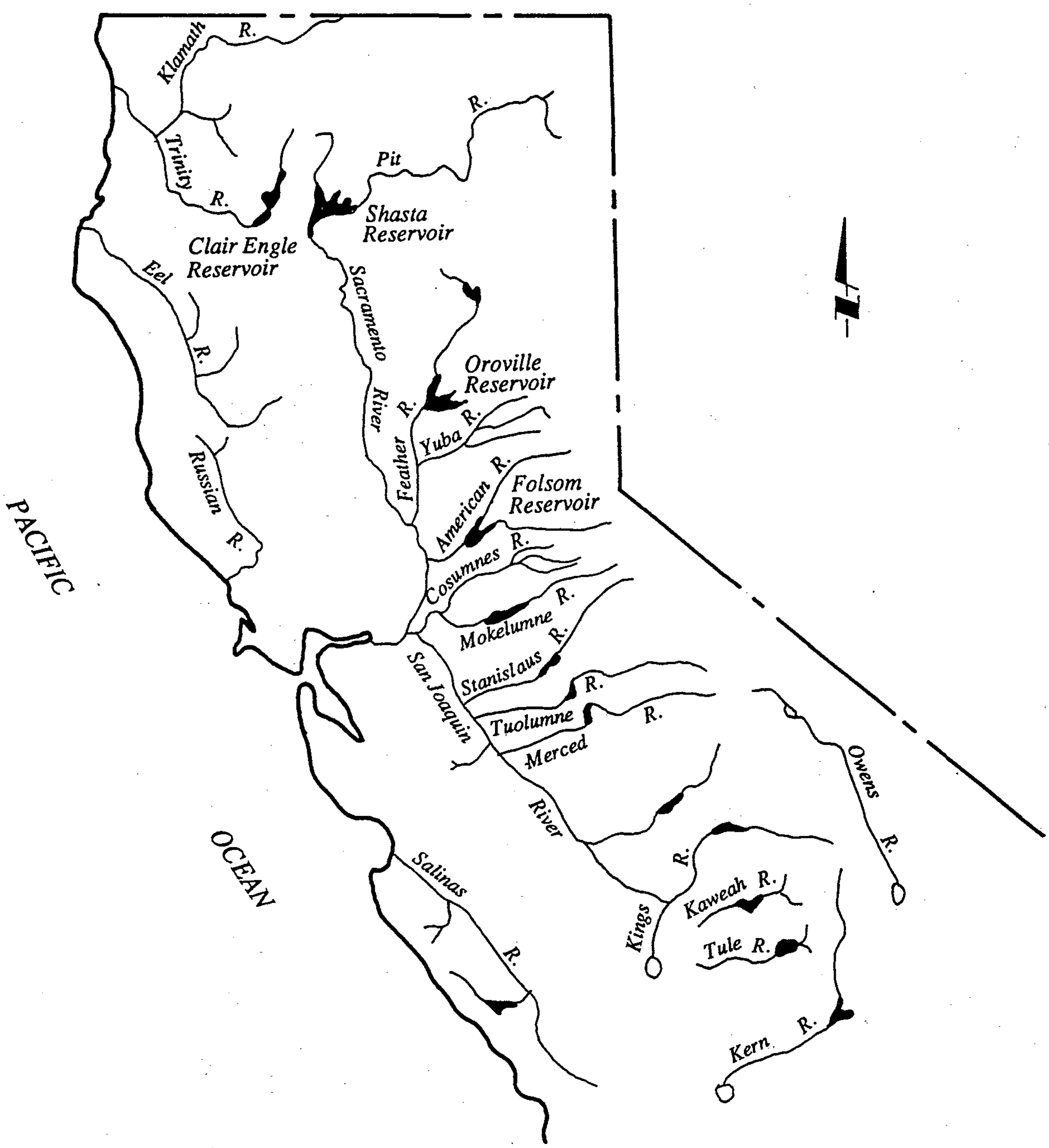

Figure A1-1.
Delta Tributaries and Upstream Reservoirs Included in the DWRSIM Statewide Water Supply Planning Model

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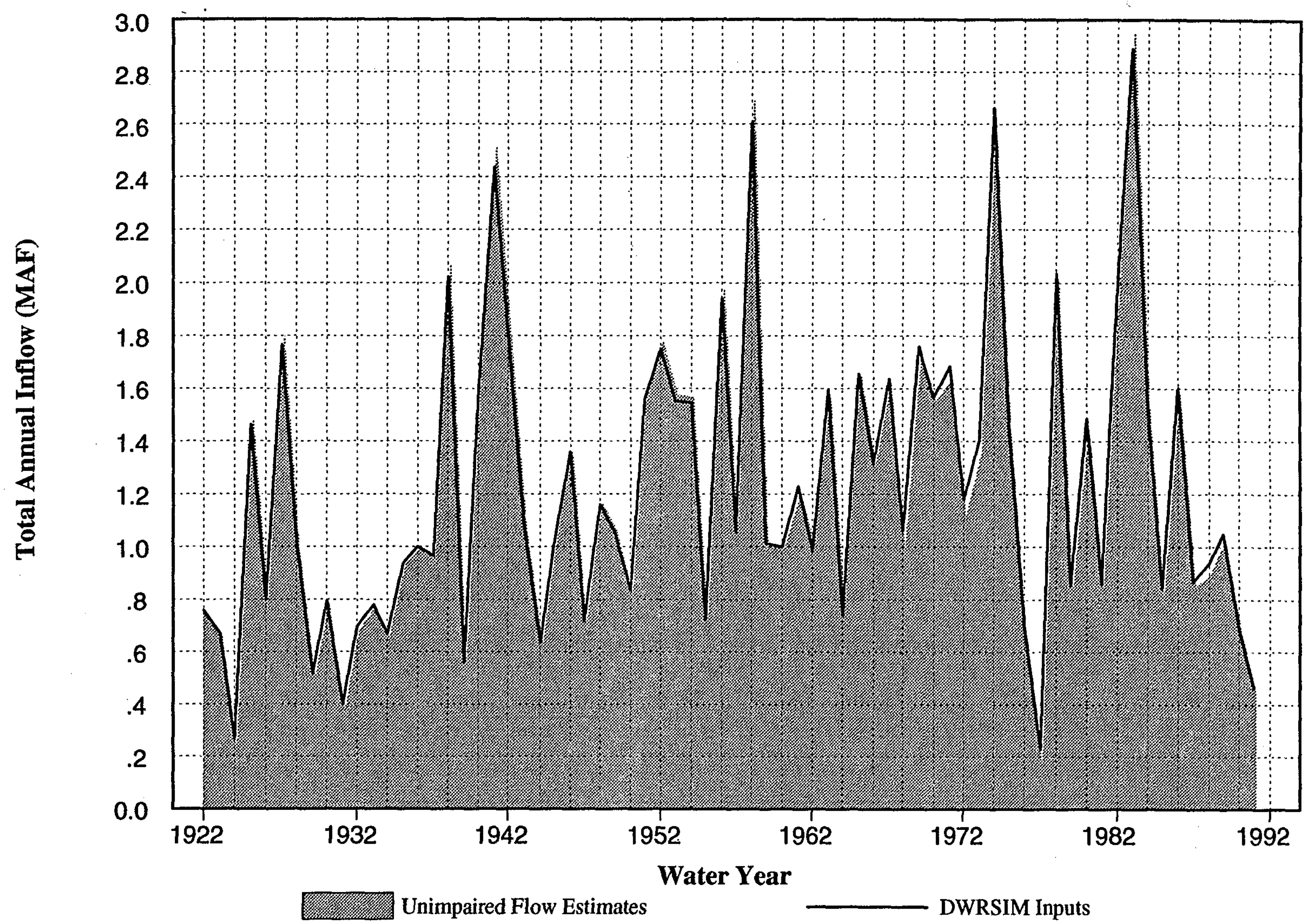

Figure A1-2.
Unimpaired Flow Estimates and DWRSIM Inputs for Total Annual Inflows to Clair Engle Reservoir for 1922-1991

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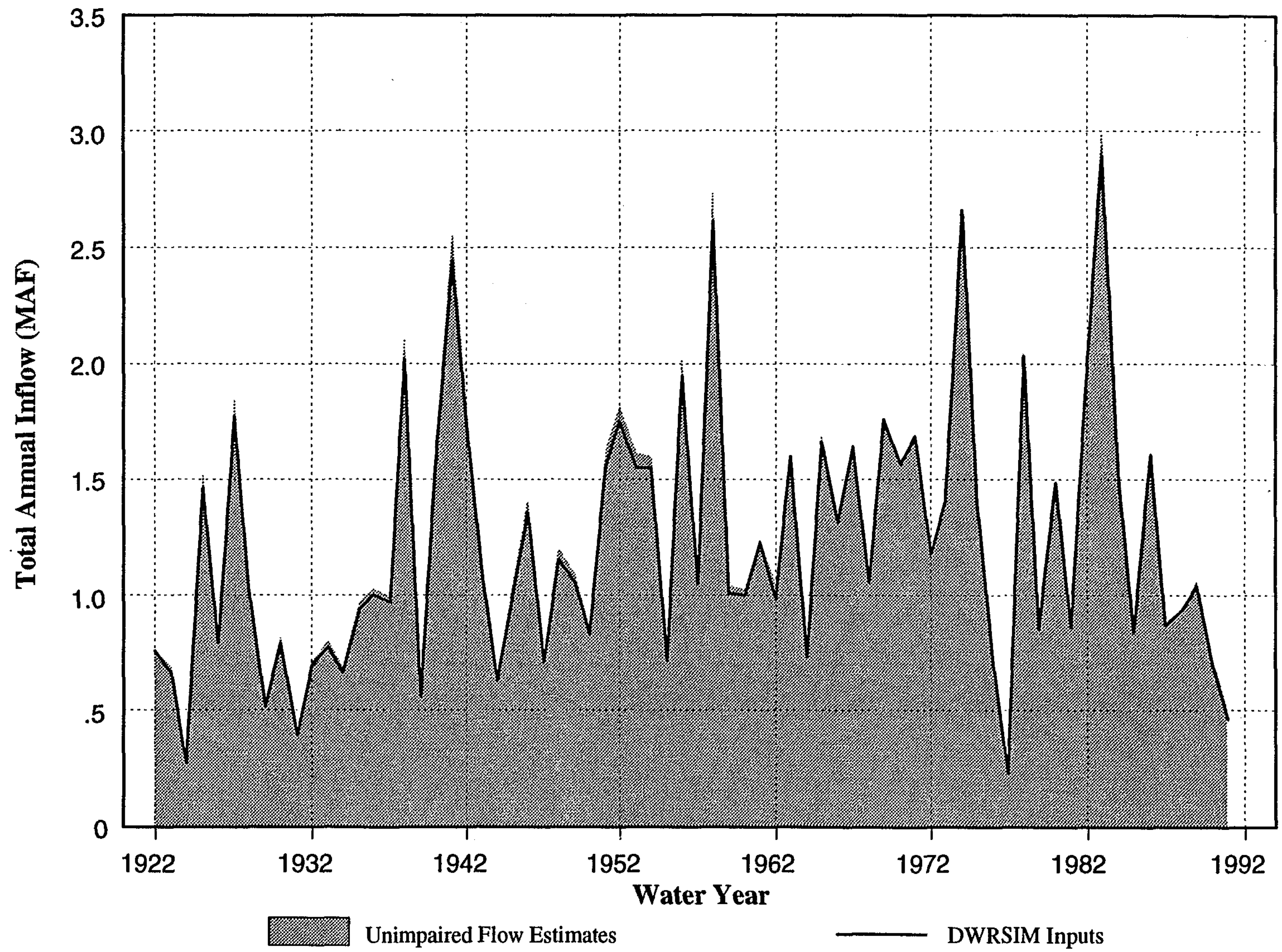

Figure A1-3.
Unimpaired Flow Estimates and DWRSIM Inputs for Total Annual Flows in the Trinity River for 1922-1991

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C-061232

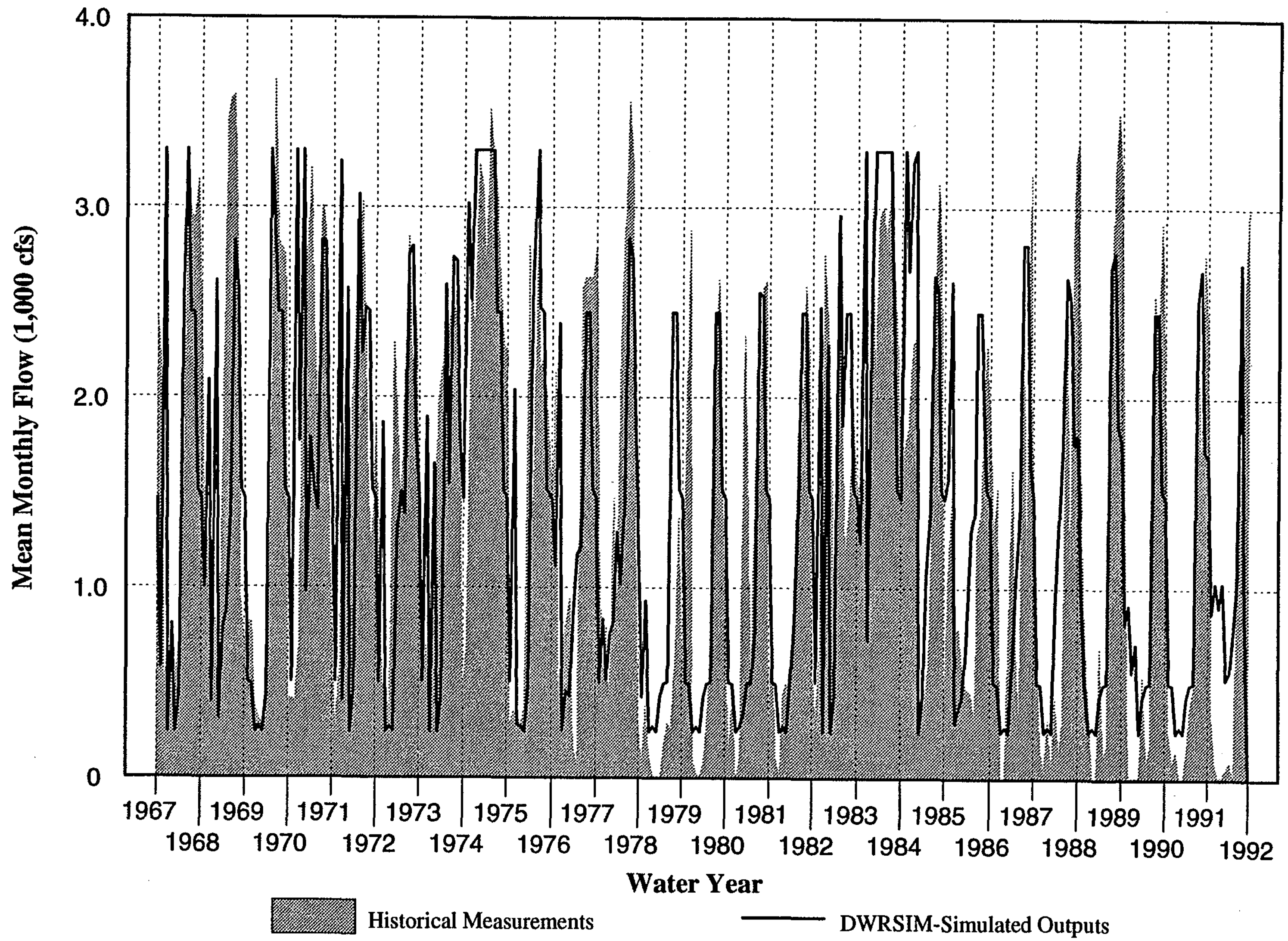

Figure A1-4.
Historical Measured and DWRSIM-Simulated Mean Monthly Diversions from the Trinity River Basin for 1967-1991

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Prepared by: Jones & Stokes Associates

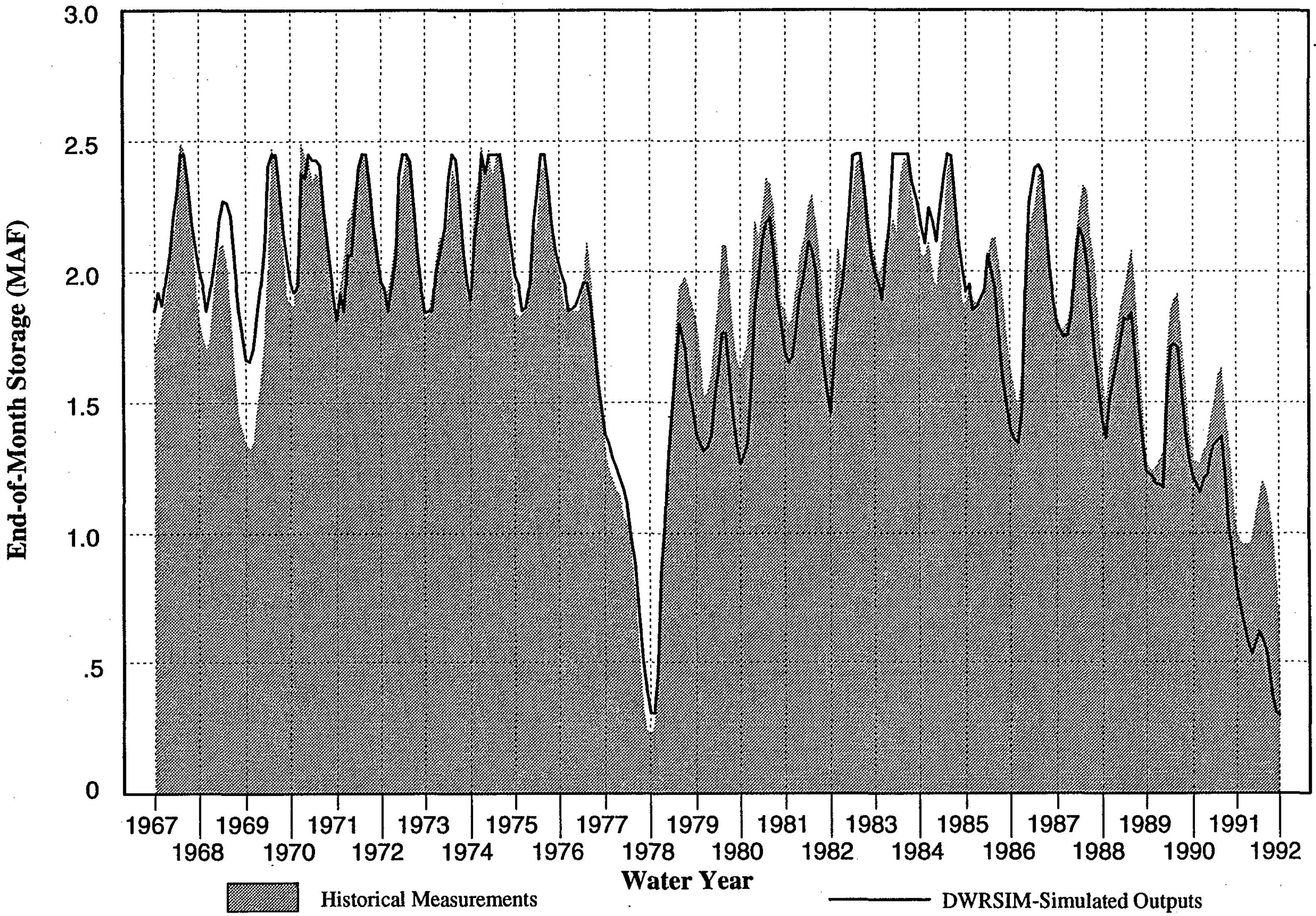

Figure A1-5.
Historical Measured and DWRSIM-Simulated End-of-Month Storage in Clair Engle Reservoir for 1967-1991

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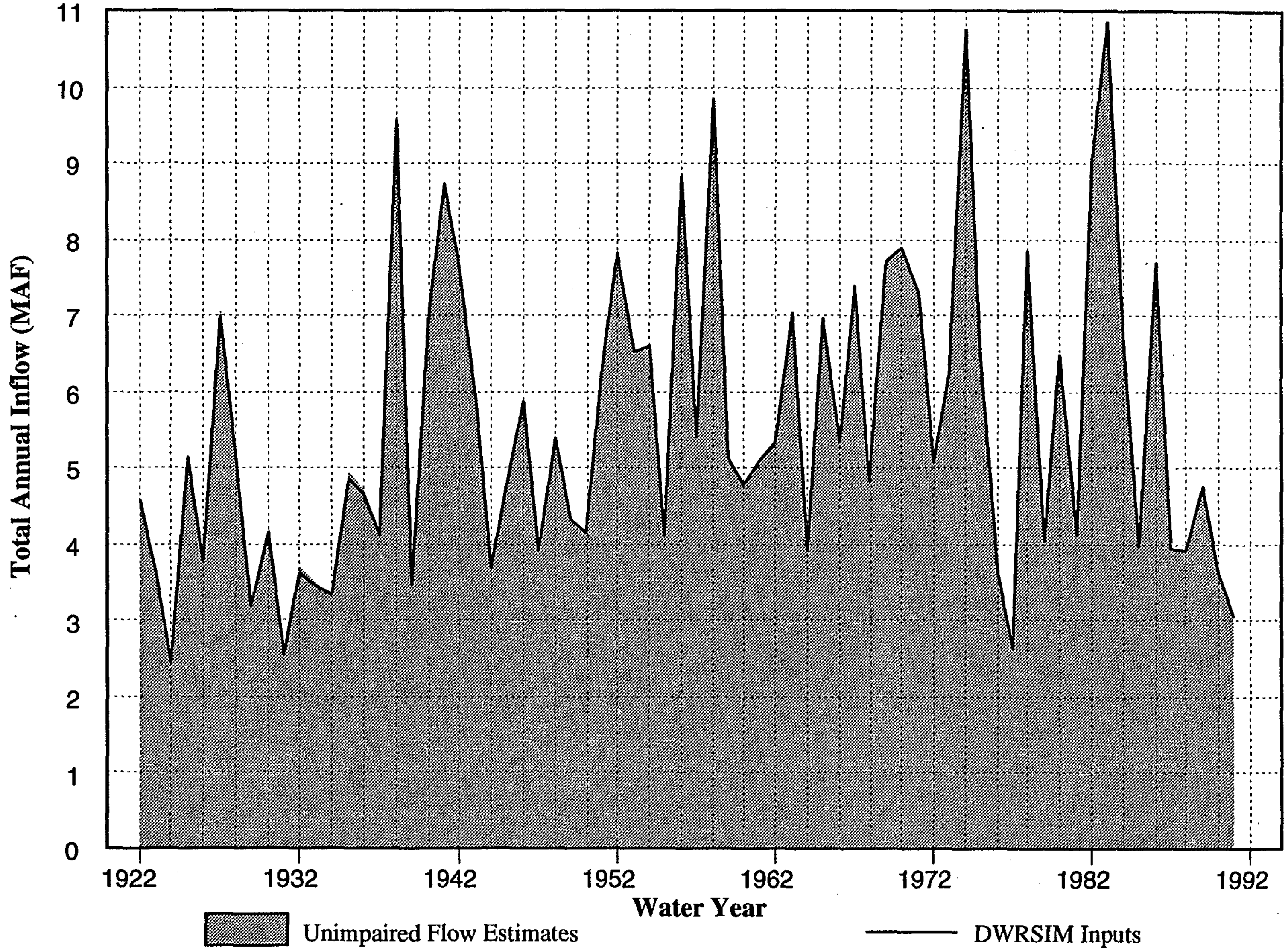

Figure A1-6.
Unimpaired Flow Estimates and DWRSIM Inputs for Total Annual Inflows to Shasta Reservoir for 1922-1991

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Prepared by: Jones & Stokes Associates

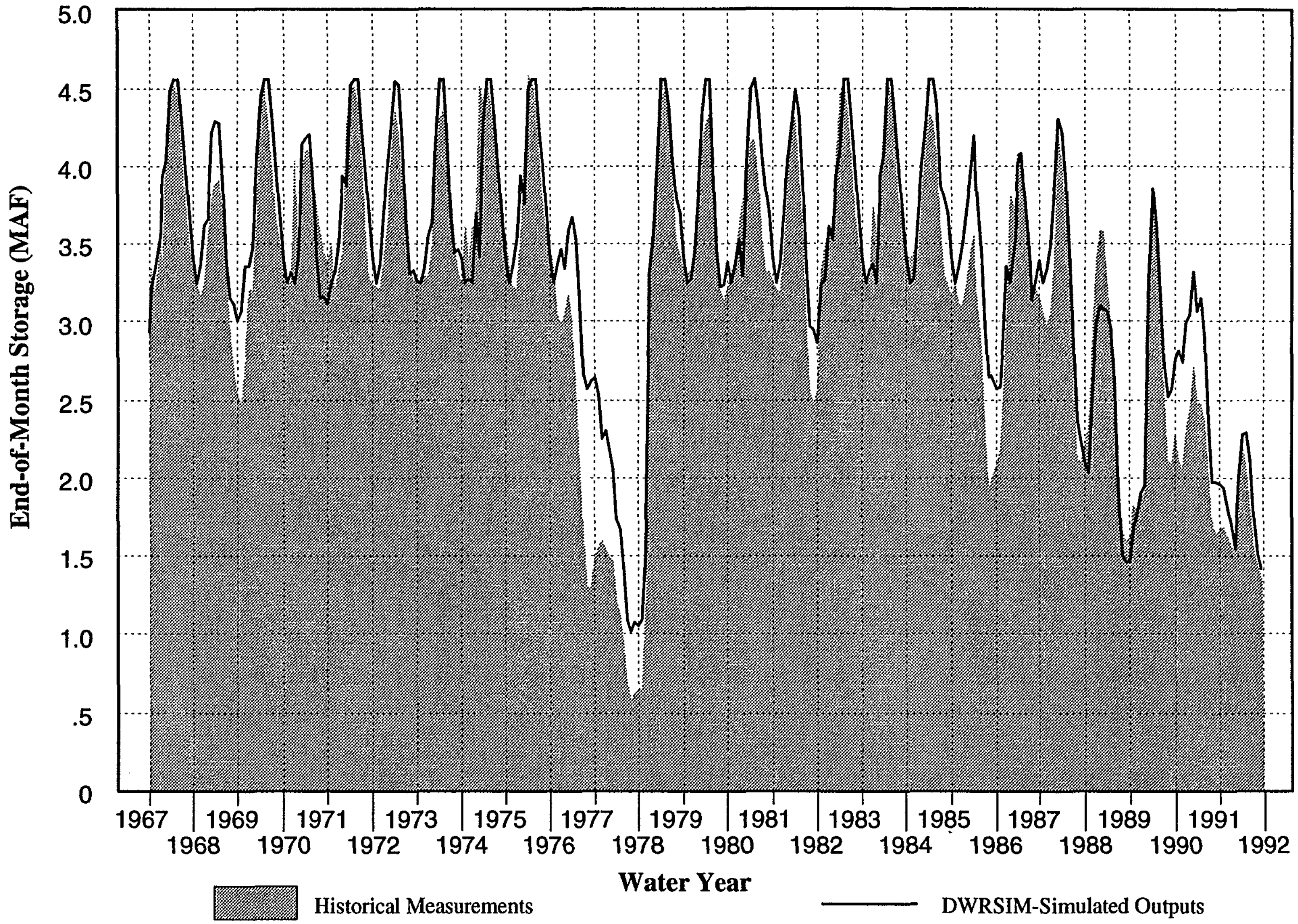

Figure A1-7.
Historical Measured and DWRSIM-Simulated End-of-Month Storage in Shasta Reservoir for 1967-1991

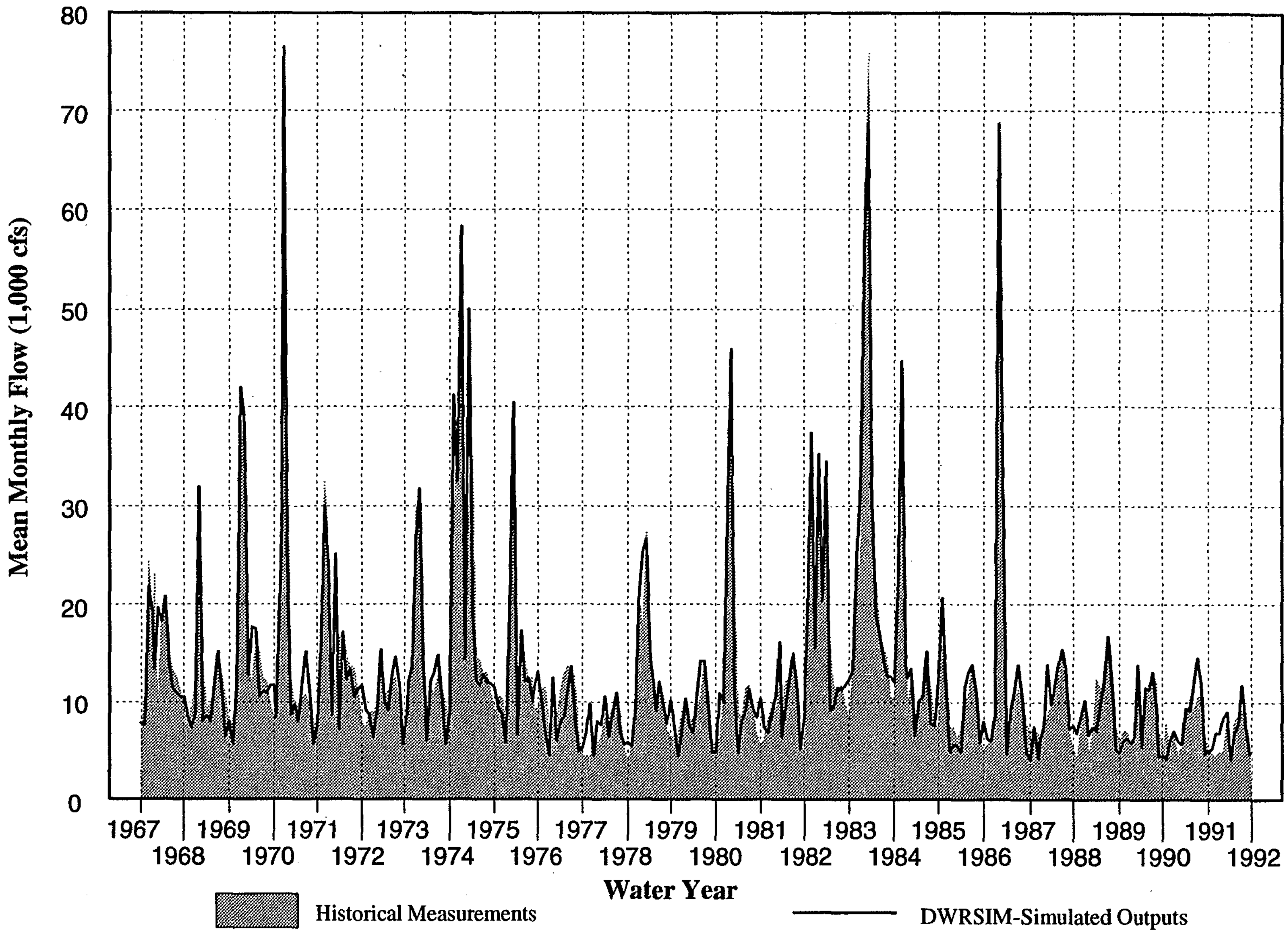

Figure A1-8.
Historical Measured and DWRSIM-Simulated Mean Monthly Flows in the Sacramento River at Bend Bridge for 1967-1991

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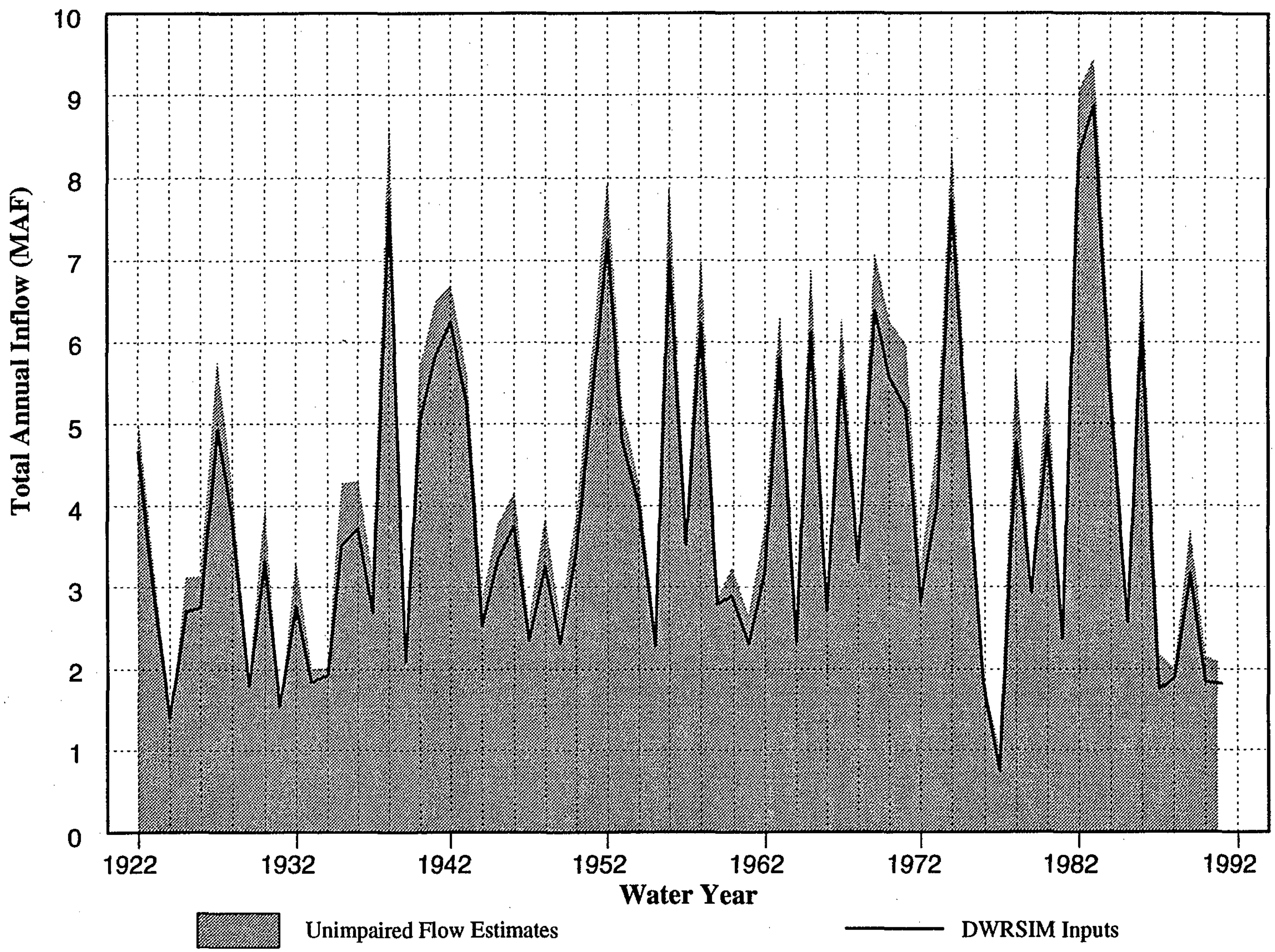

Figure A1-9.
Unimpaired Flow Estimates and DWRSIM Inputs for Total Annual Inflows to Oroville Reservoir for 1922-1991

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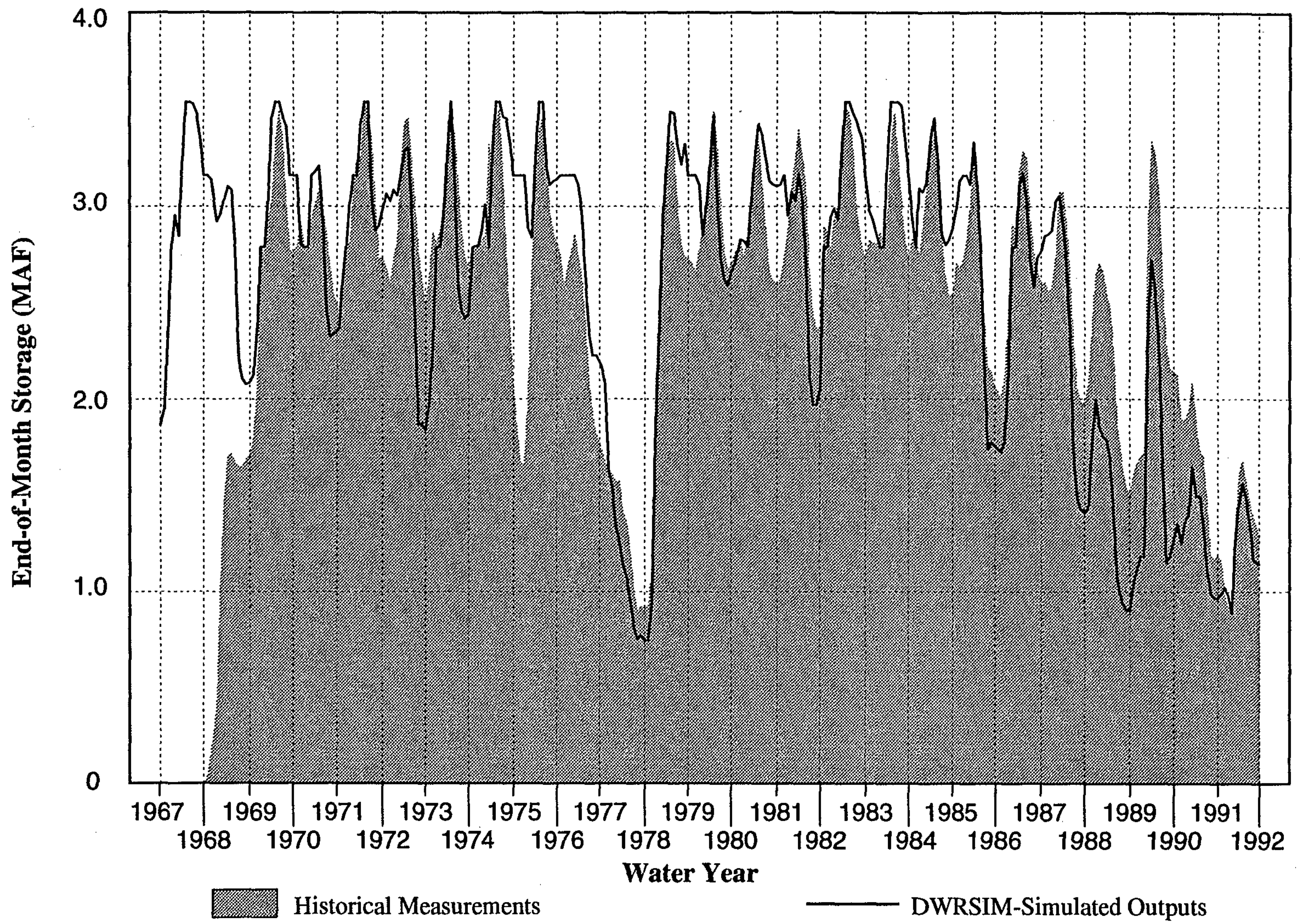

Figure A1-10.
Historical Measured and DWRSIM-Simulated End-of-Month Storage in Oroville Reservoir for 1967-1991

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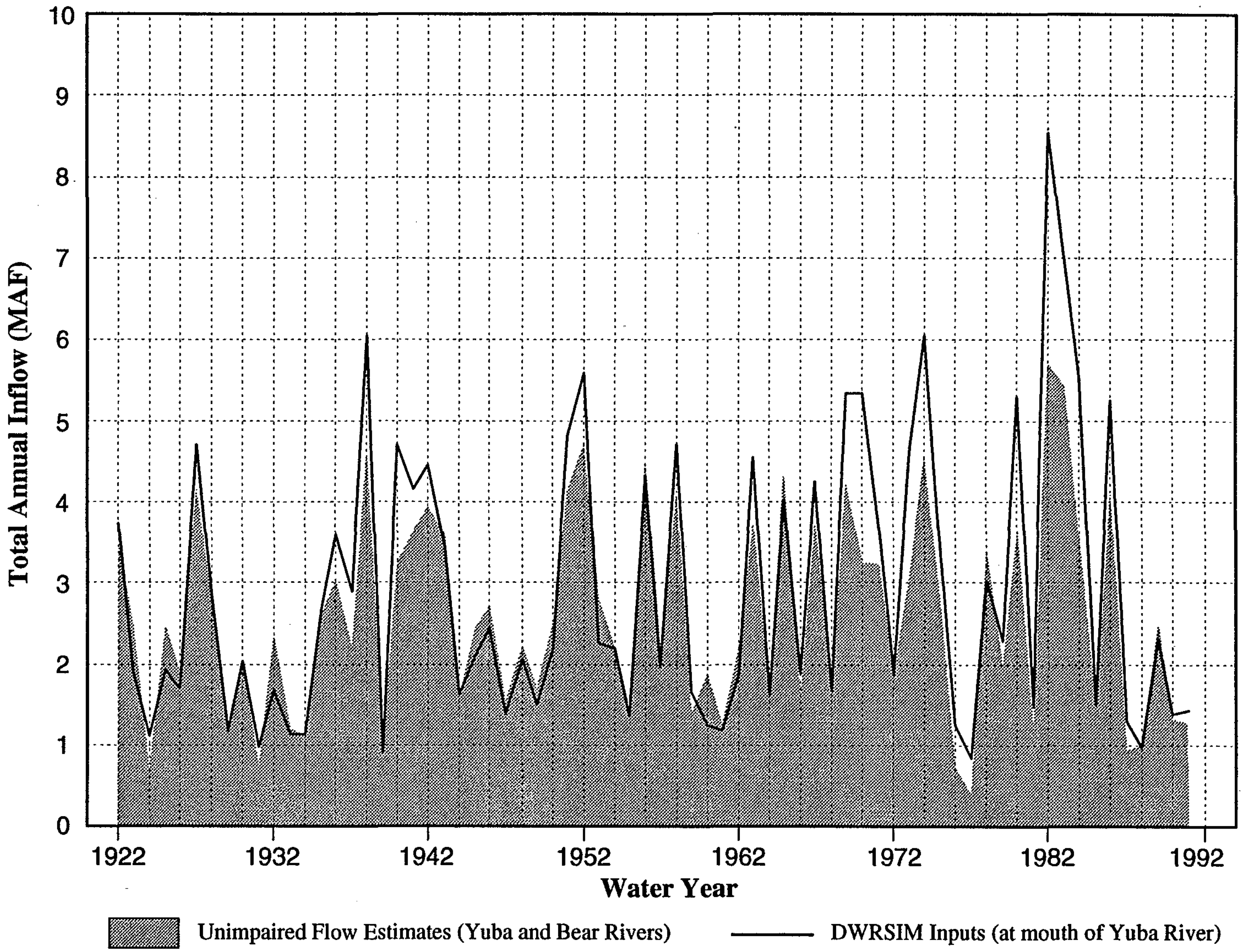

Figure A1-11.
Unimpaired Flow Estimates for the Yuba and Bear Rivers, and
DWRSIM Inputs for Total Annual Gains to the Feather River for 1922-1991

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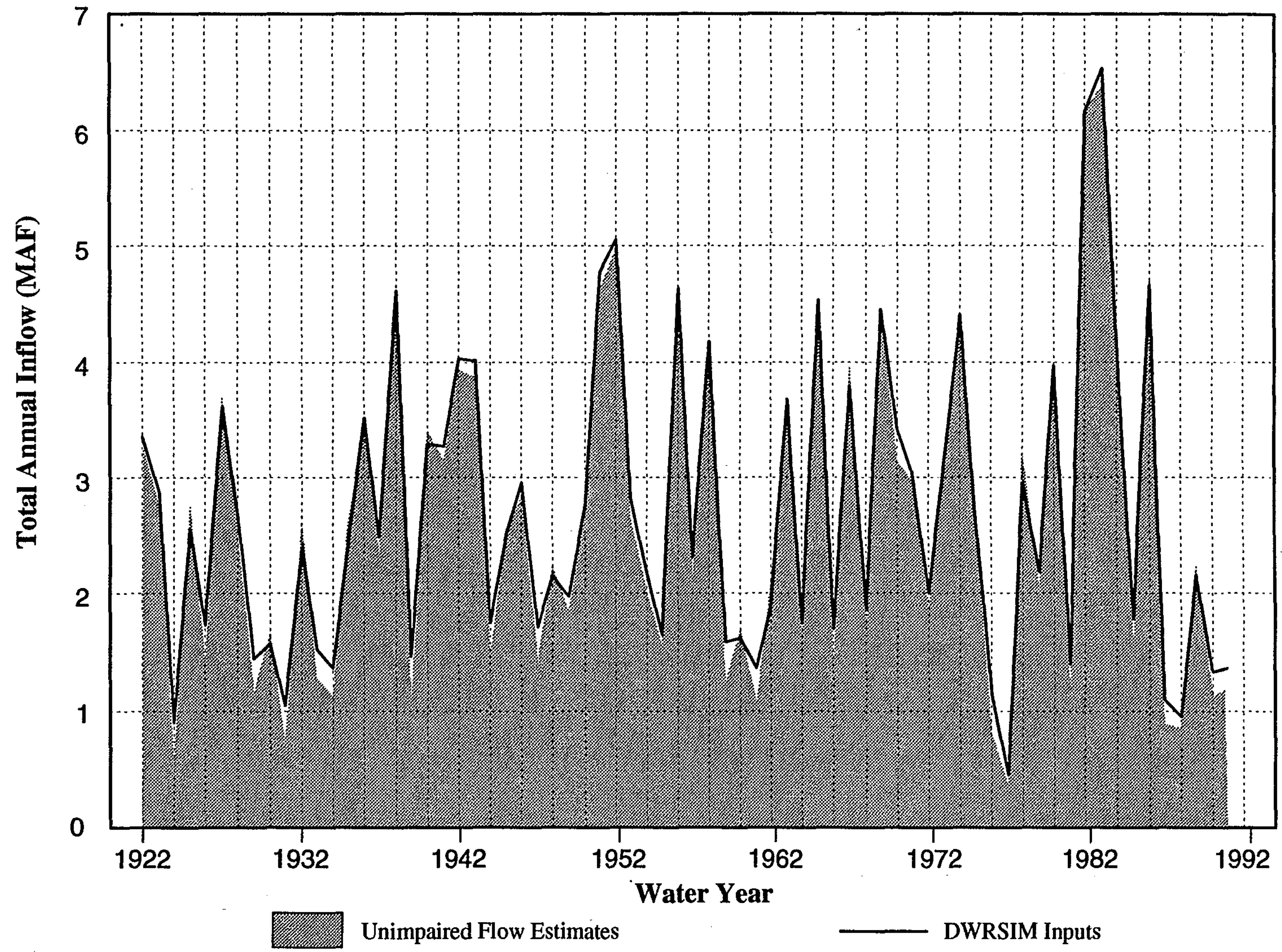

Figure A1-12.
Unimpaired Flow Estimates and DWRSIM Inputs for Total Annual Inflows to Folsom Reservoir for 1922-1991

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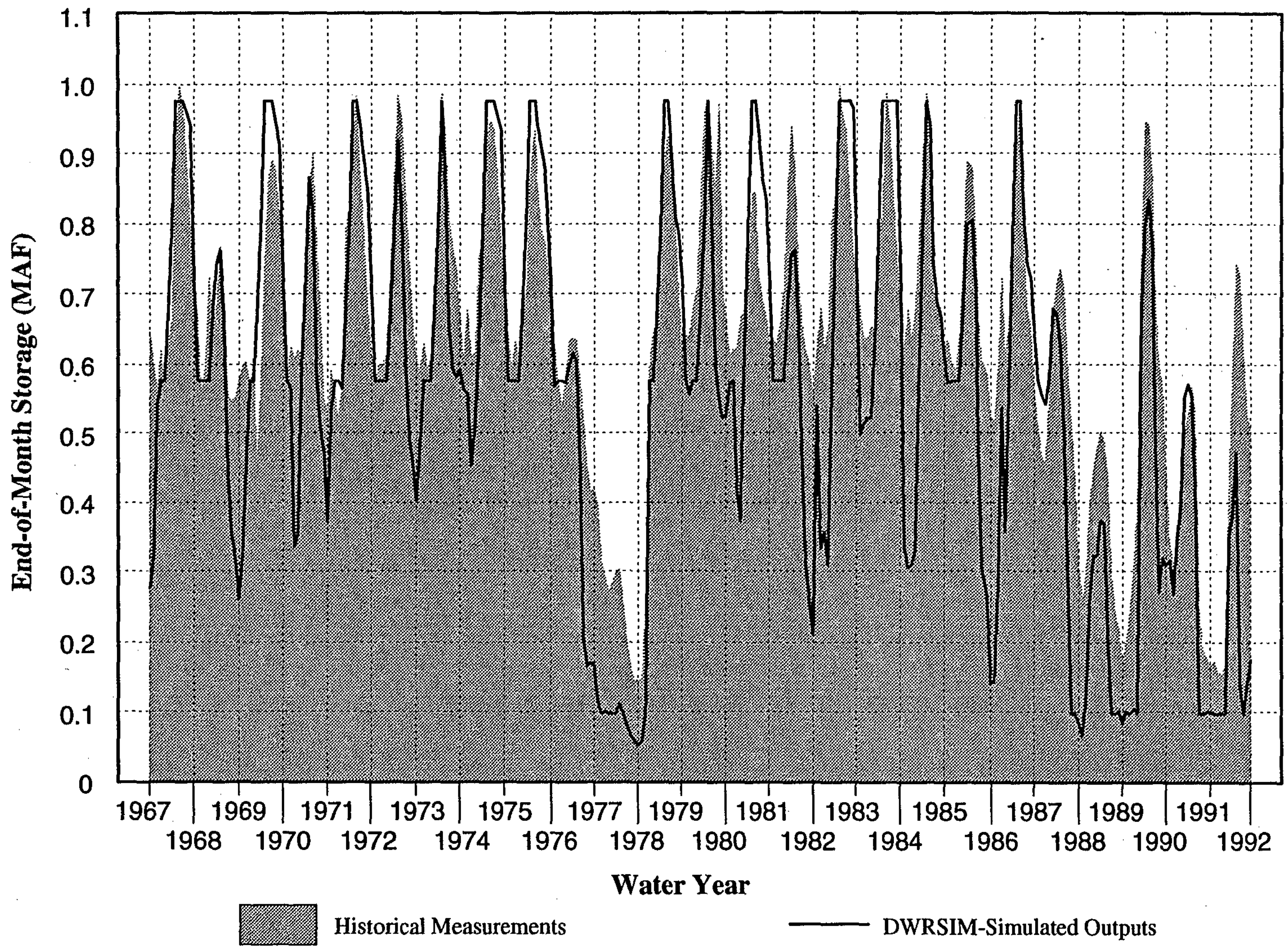

Figure A1-13.
Historical Measured and DWRSIM-Simulated End-of-Month Storage in Folsom Reservoir for 1967-1991

DELTA WETLANDS
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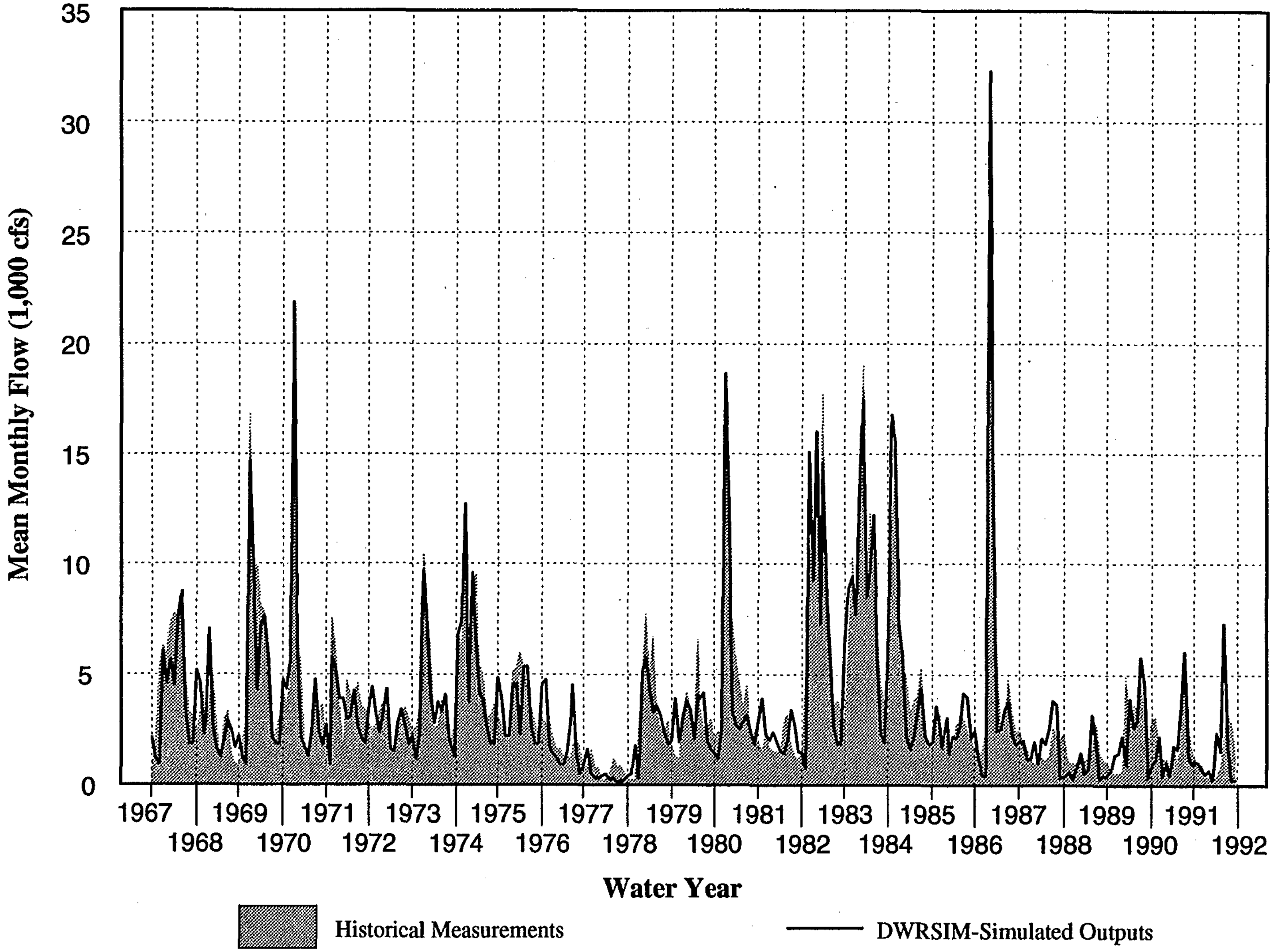

Figure A1-14.
Historical Measured and DWRSIM-Simulated Mean Monthly Flows in the American River at Fair Oaks for 1967-1991

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Prepared by: Jones & Stokes Associates

C-061243

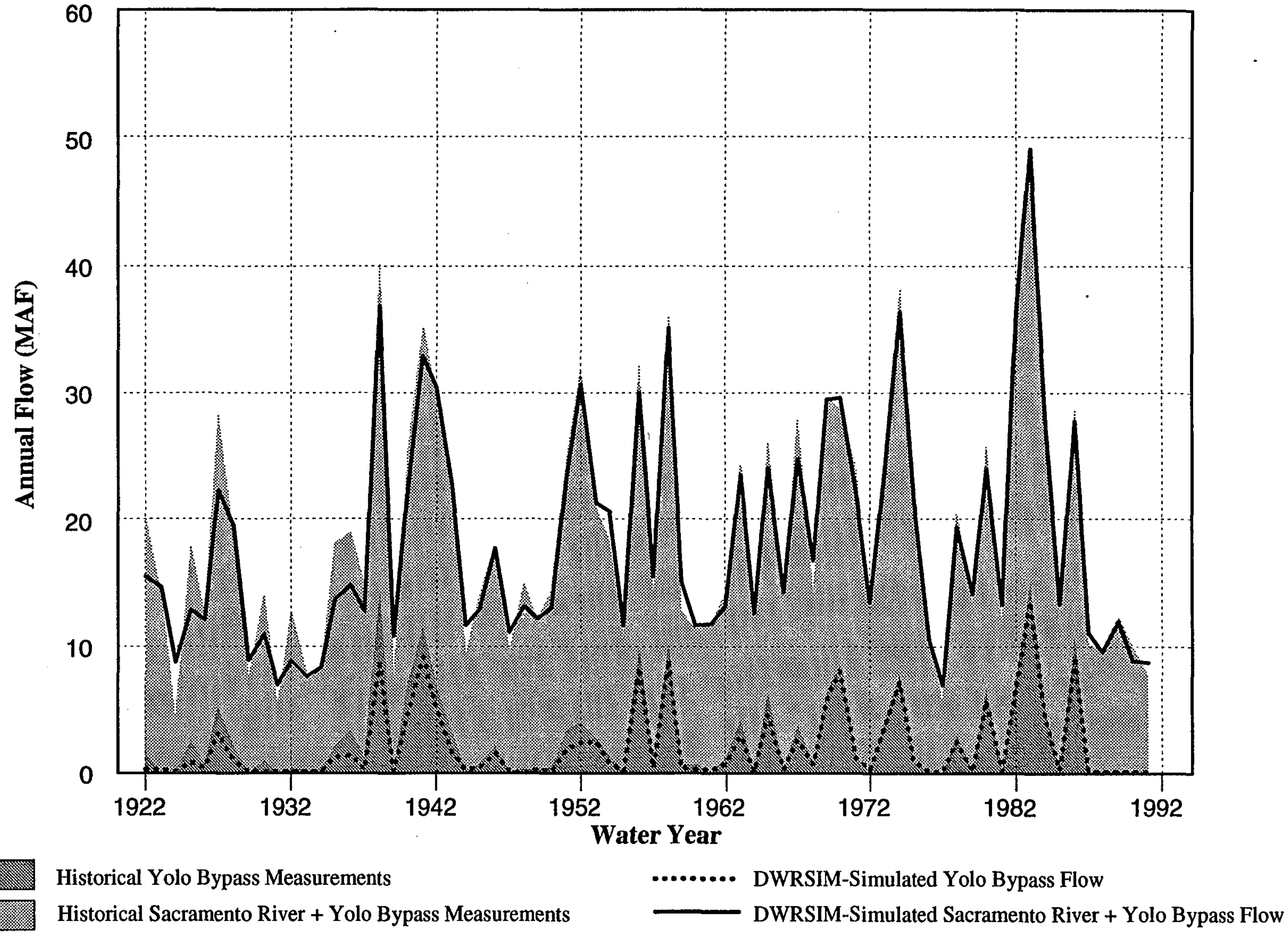

Figure A1-15.
Historical Measured and DWRSIM-Simulated Total Annual Delta Inflows from Yolo Bypass and the Sacramento River at Freeport for 1922-1991

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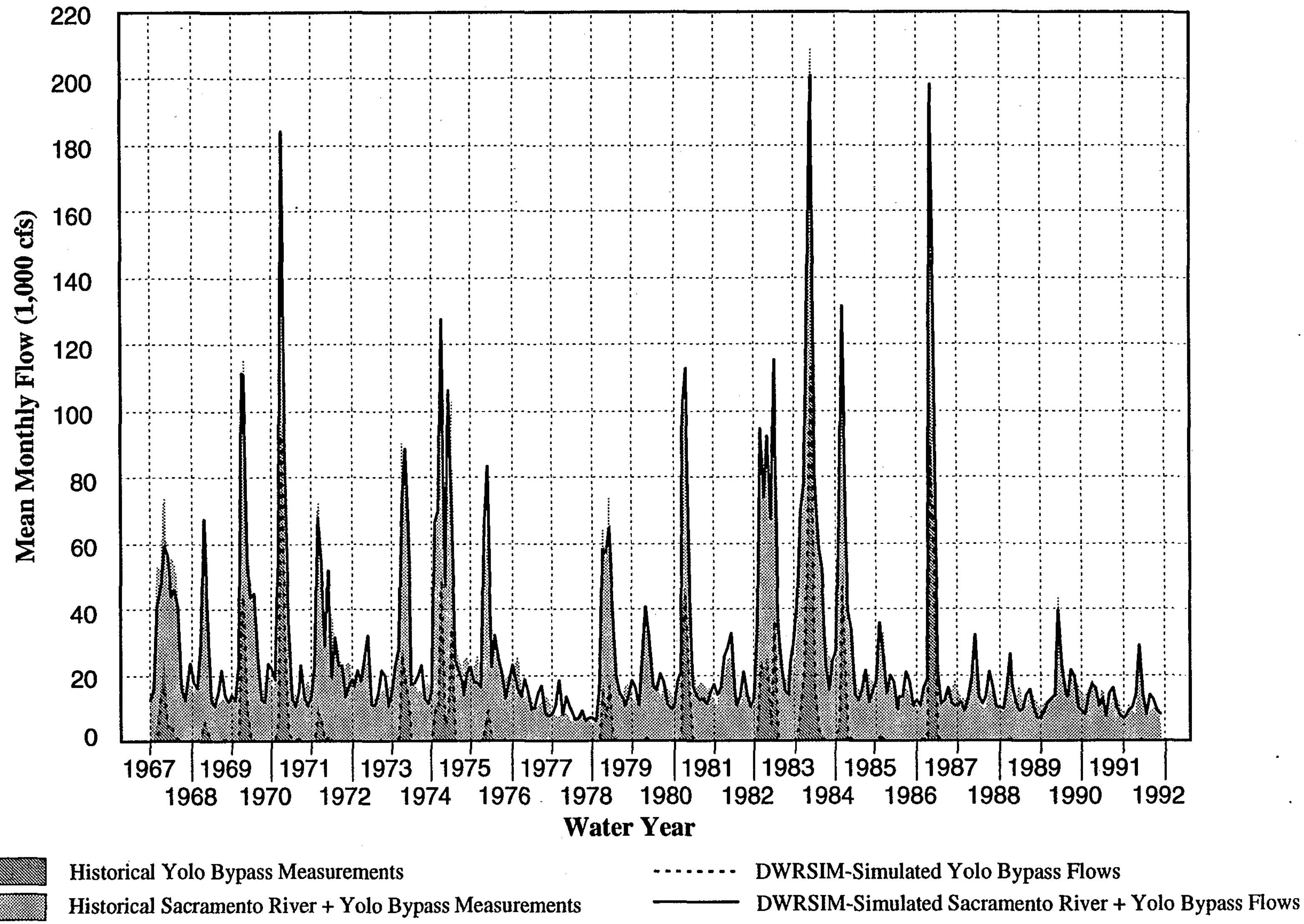

Figure A1-16.
Historical Measured and DWRSIM-Simulated Mean Monthly Flows in Yolo Bypass and the Sacramento River at Freeport for 1967-1991

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Prepared by: Jones & Stokes Associates

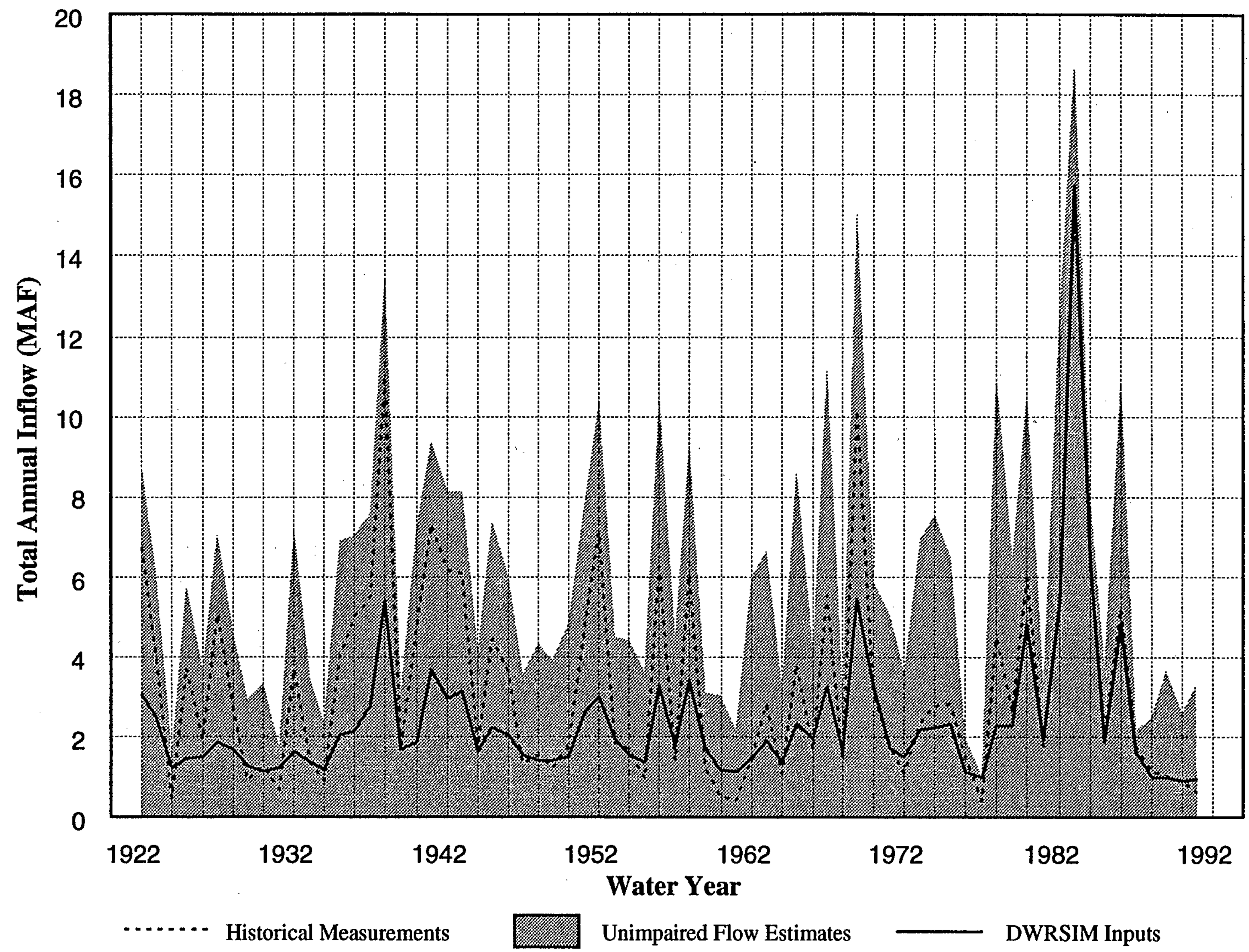

Figure A1-17.
Historical Measurements, Unimpaired Flow Estimates, and DWRSIM Inputs for Total Annual Flows in the San Joaquin River at Vernalis for 1922-1991

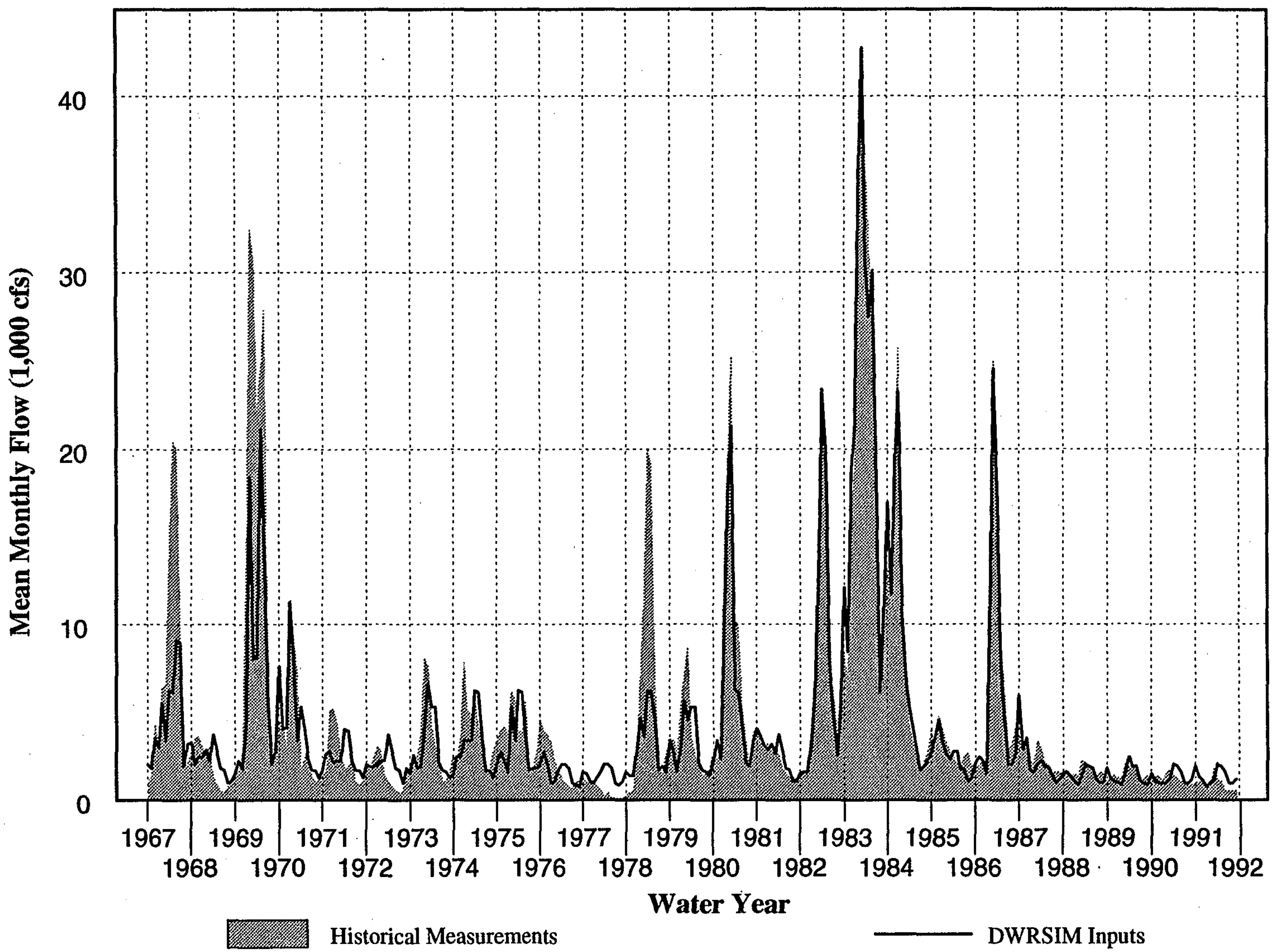

Figure A1-18.
Historical Measurements and DWRSIM Inputs for Mean Monthly Flows in the San Joaquin River at Vernalis for 1967-1991

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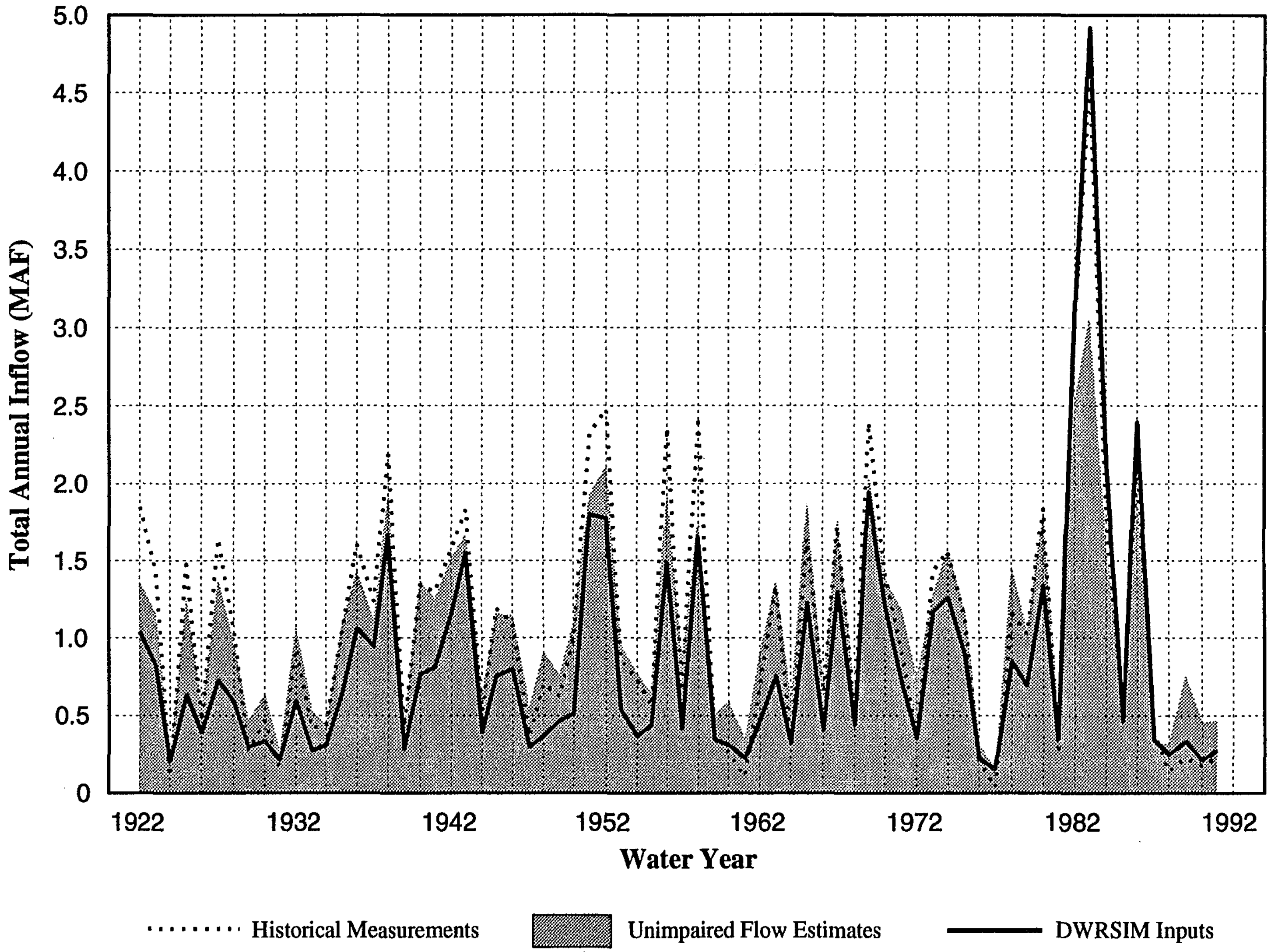

Figure A1-19.
Historical Measurements, Unimpaired Flow Estimates, and DWRSIM Inputs for Total Annual Inflows to the Delta from Eastside Streams for 1922-1991

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Prepared by: Jones & Stokes Associates

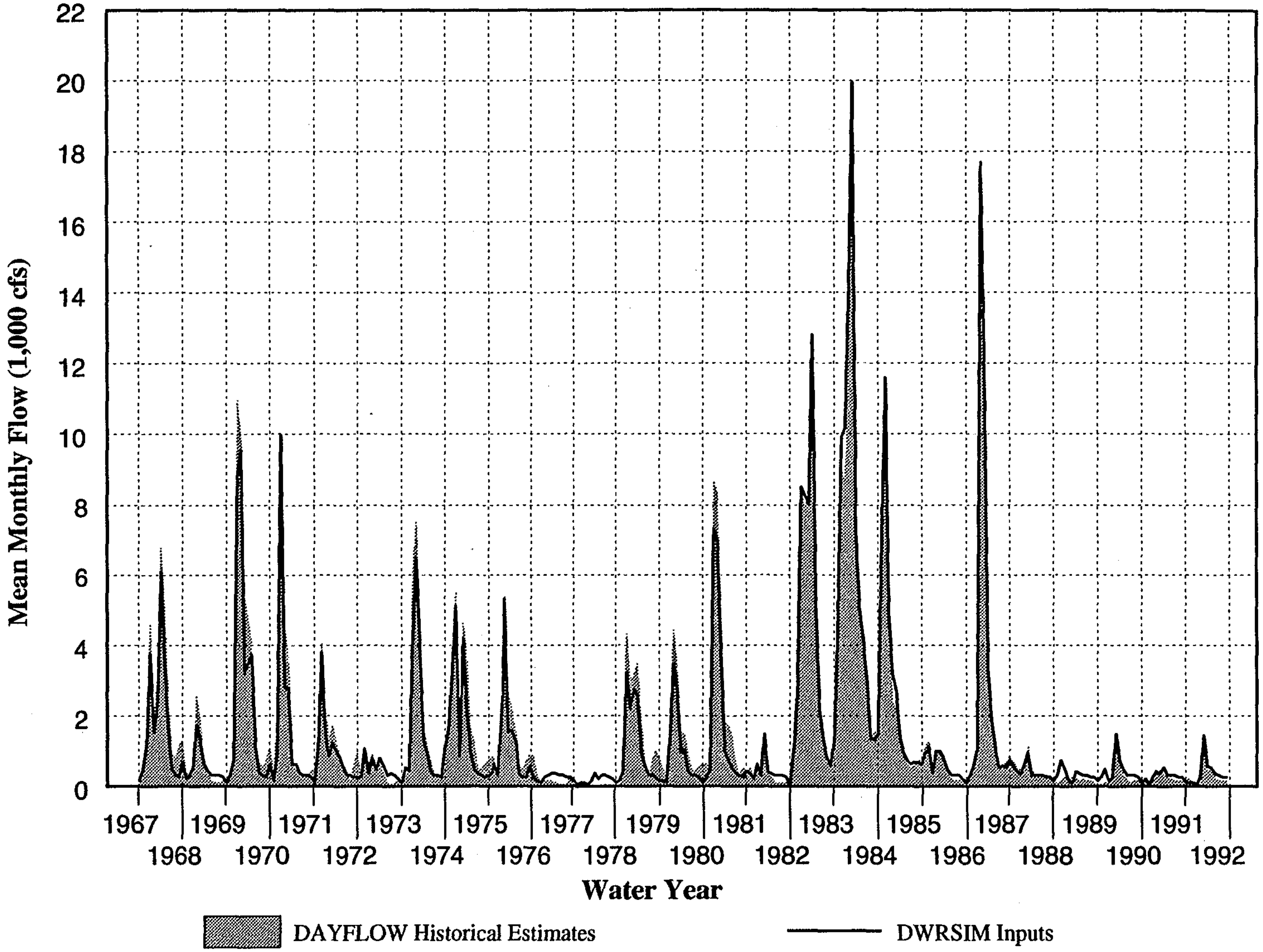

Figure A1-20.
DAYFLOW Historical Measurements and DWRSIM Inputs for Mean Monthly Inflows to the Delta from Eastside Streams for 1967-1991

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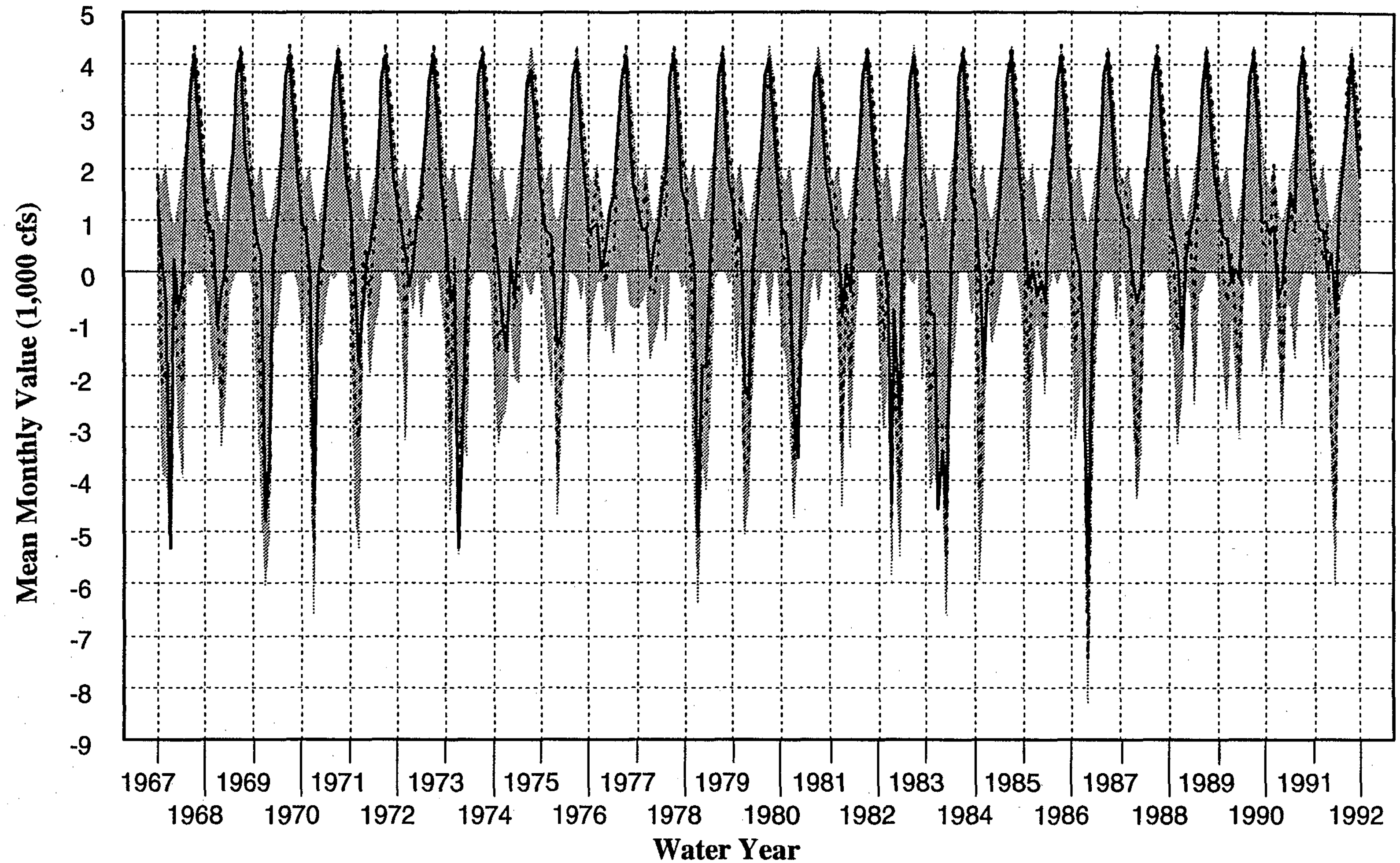

Figure A1-21.
Mean Monthly DAYFLOW Estimated Consumptive Use, Precipitation and Net Channel Depletion and DWRSIM Net Channel Depletion Inputs for the Delta for 1968-1991

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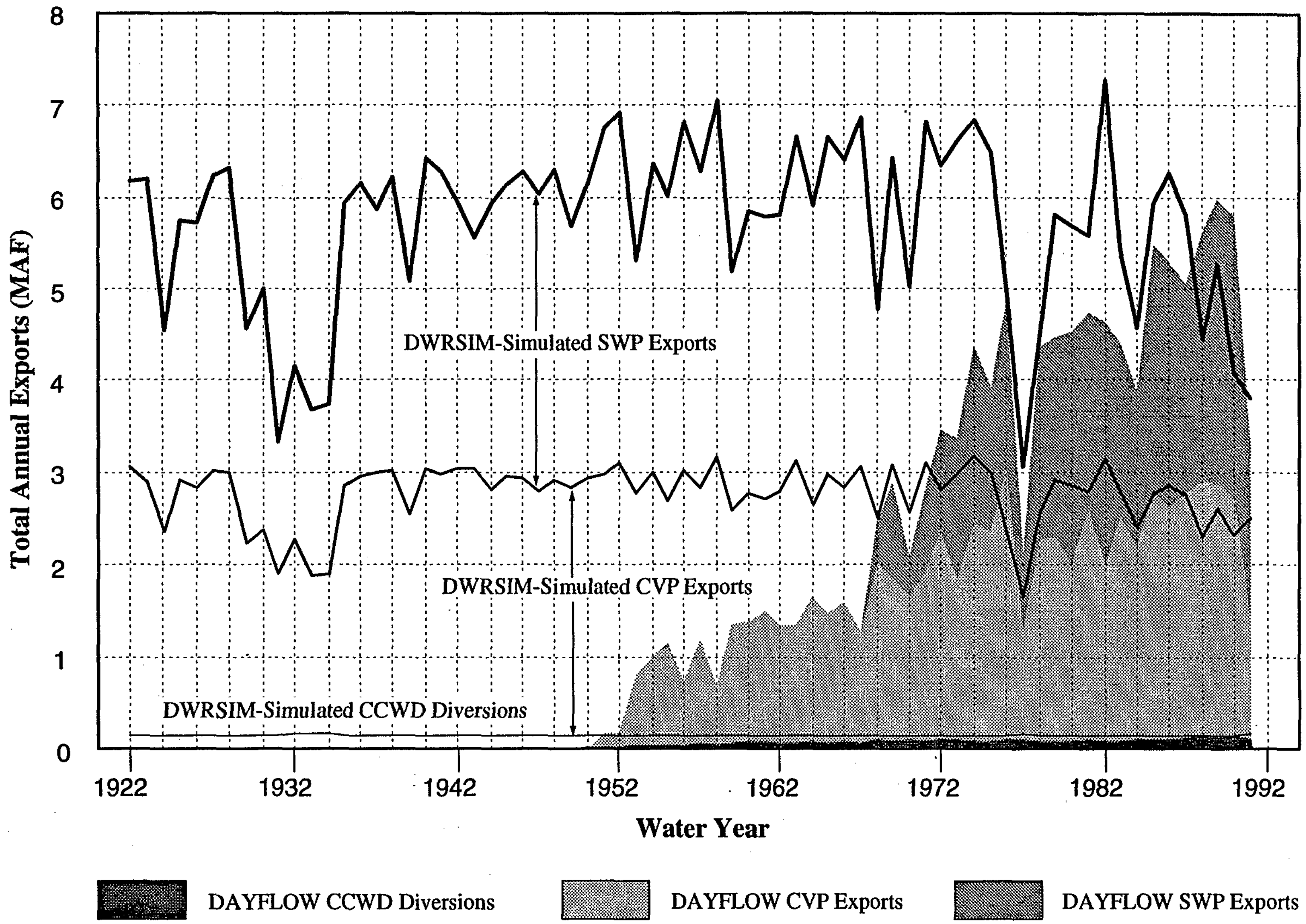

Figure A1-22.
DAYFLOW Historical and DWRSIM-Simulated Total Annual CVP and SWP Delta Exports and CCWD Diversions for 1922-1991

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Prepared by: Jones & Stokes Associates

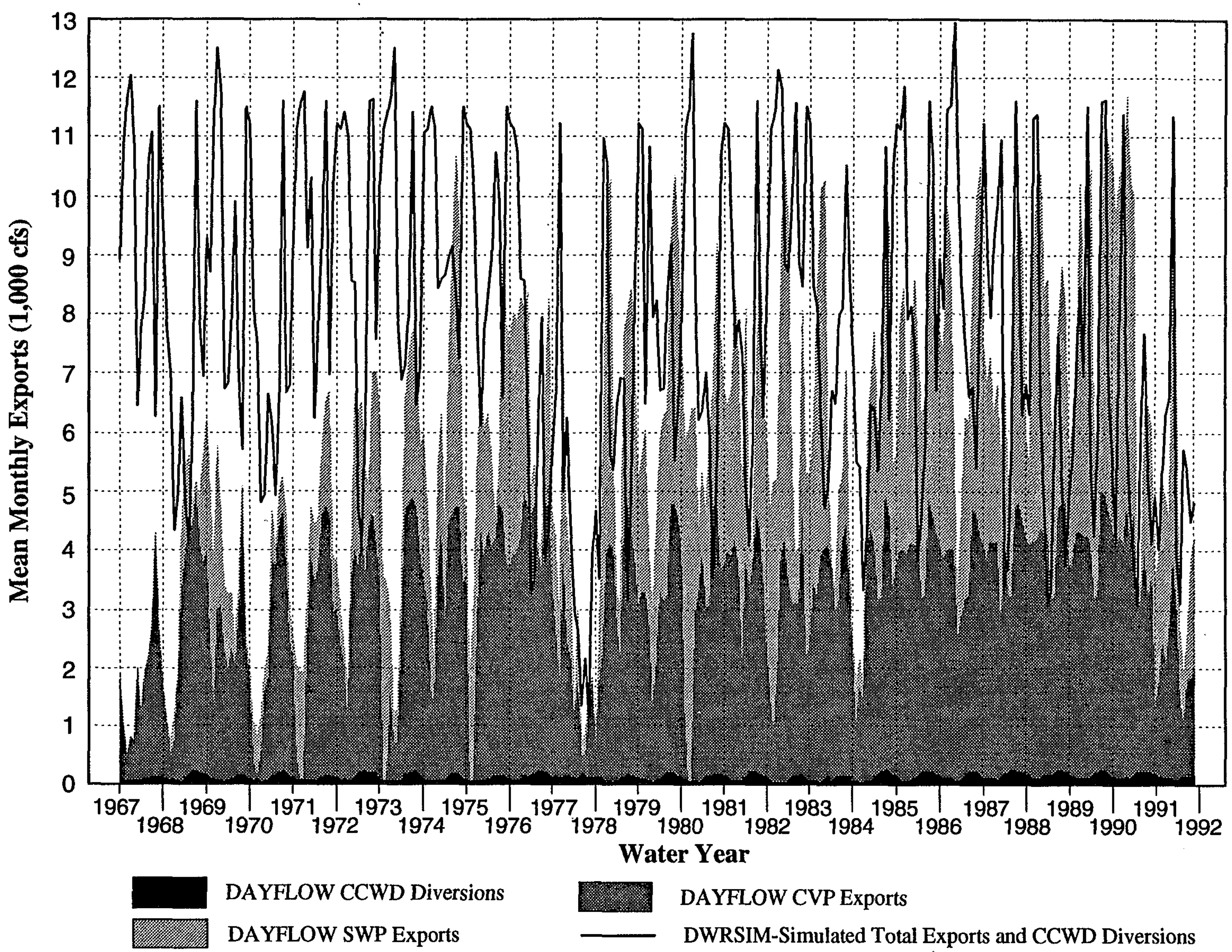

Figure A1-23.
DAYFLOW Historical and DWRSIM-Simulated Mean Monthly Delta CVP and SWP Exports and CCWD Diversions for 1967-1991

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Prepared by: Jones & Stokes Associates

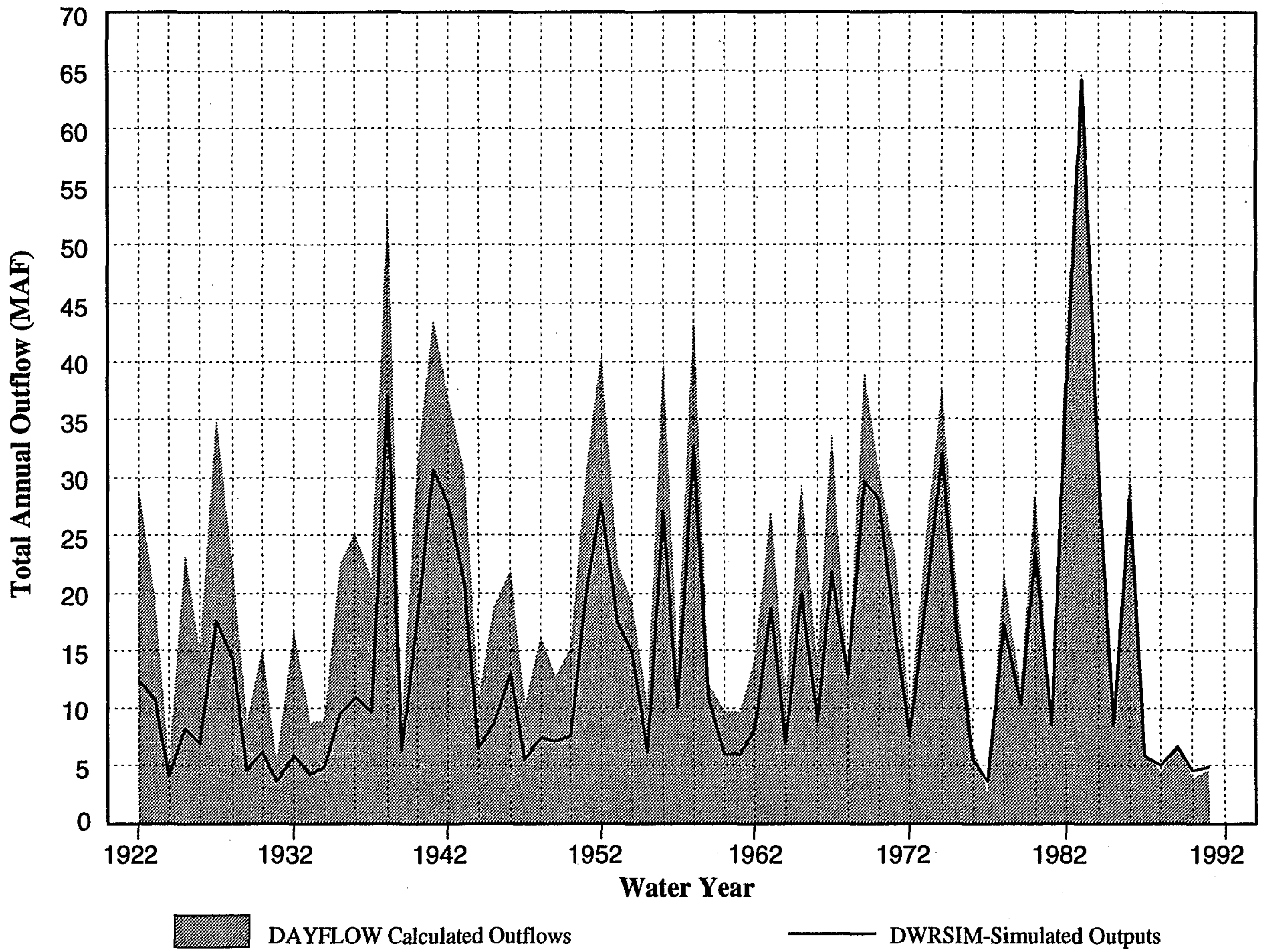

Figure A1-24.
DAYFLOW Calculated and DWRSIM-Simulated Total Annual Delta Outflows for 1922-1991

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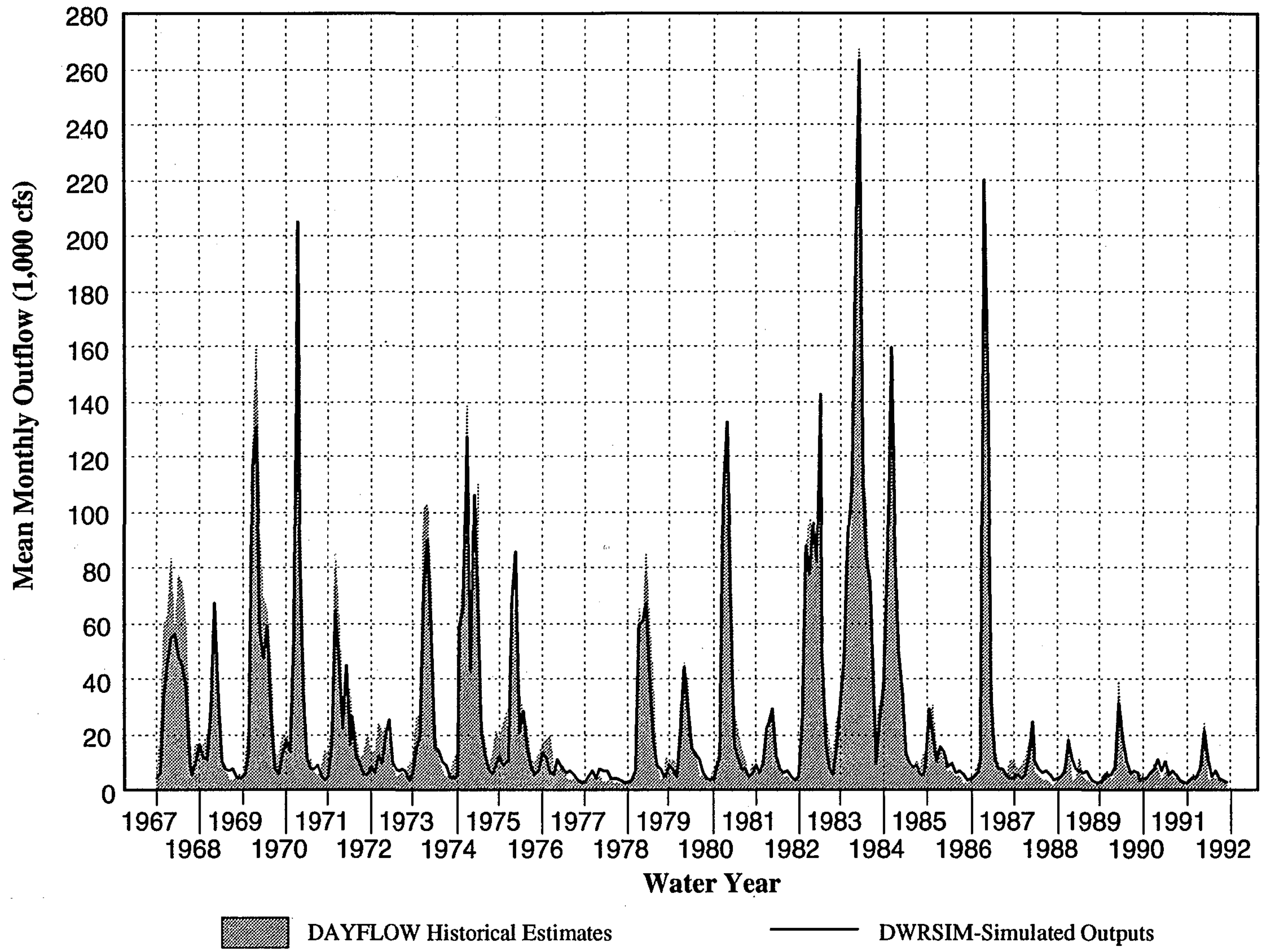

Figure A1-25.
DAYFLOW Historical and DWRSIM-Simulated Mean Monthly Delta Outflows for 1967-1991

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